Spaceflight

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COVER:

Launched from a B-52 at 38,000-ft., a North American X-15 embarks on a successful powered flight.

Photo: *North American Aviation*

Professor Alla Masevich

At a special meeting of the Society on 10 February, we were pleased to welcome Professor A. G. Masevich, the distinguished woman astronomer who is vice-president of the Astronomical Council of the U.S.S.R. Academy of Sciences.

The Hoare Memorial Hall at Church House, Westminster, was packed when Professor Masevich gave her lecture on "Space Research in the Soviet Union." She spoke first of the organization of Moonwatch tracking stations in the Soviet Union, in which she has played a leading rôle, and subsequently of the geophysical measurements obtained with the three Soviet satellites and the Lunik probes.

It was interesting to learn from her remarks about Lunik III that the celebrated pictures of the Moon's hidden face were obtained by superimposing a number of the best photographs of selected areas; also that had radio contact with the probe not ceased abruptly after the pictures were transmitted—it was thought due to meteorite damage—that the entire film could have been run through for a second time when the vehicle was much nearer the Earth. This, Professor Masevich felt, would have provided pictures of higher definition.

Blue Streak

We devote a large part of the current issue to the Weapons Research Establishment in Australia, soon to receive the first of the Blue Streak L.R.B.M. test-vehicles.

This signal event in British rocketry marks not only the emergence of Britain as a "ballistic Power" but heralds what we all hope will be a new epoch in British Commonwealth science and technology.

As Mr. Duncan Sandys, the Minister of Aviation, has pointed out, a combination of Blue Streak, Black Knight and a "solid" rocket should be capable of placing nearly a ton of equipment in close-orbit around the Earth. This compares with 150-lb. available with the American Scout rocket we shall be using for initial satellite experiments in 1961.

Having gone so far in the development of suitable "hardware" ourselves, it would be unthinkable that the relatively small step of combining these rockets into one efficient satellite launcher should not be taken.

If we fail to grasp this opportunity, we may rapidly lose our technical competence in high-performance rocketry. We can no more afford this than allow our aircraft industry to decline while we rely exclusively on American airliners and transports.

The time has come to reassert ourselves in the world of science and discovery and positively to seek ways of advancing our own technology in the space-sciences. The negative attitude of shying away from important new technical developments on grounds of cost is not helpful to the nation, nor is it likely to advance the fortunes of Britain and the Commonwealth in the world of ideas.

It would be far more worthwhile if the bodies set up to advise the Government on these matters were to produce some positive suggestions on how our affairs could be so organized that we *can* contribute, within reasonable economic limits.

One would have thought that, as a first step, Commonwealth governments might have been approached on the desirability of establishing a Commonwealth Space Authority. To our knowledge, no such step has been officially discussed.

K. W. G.

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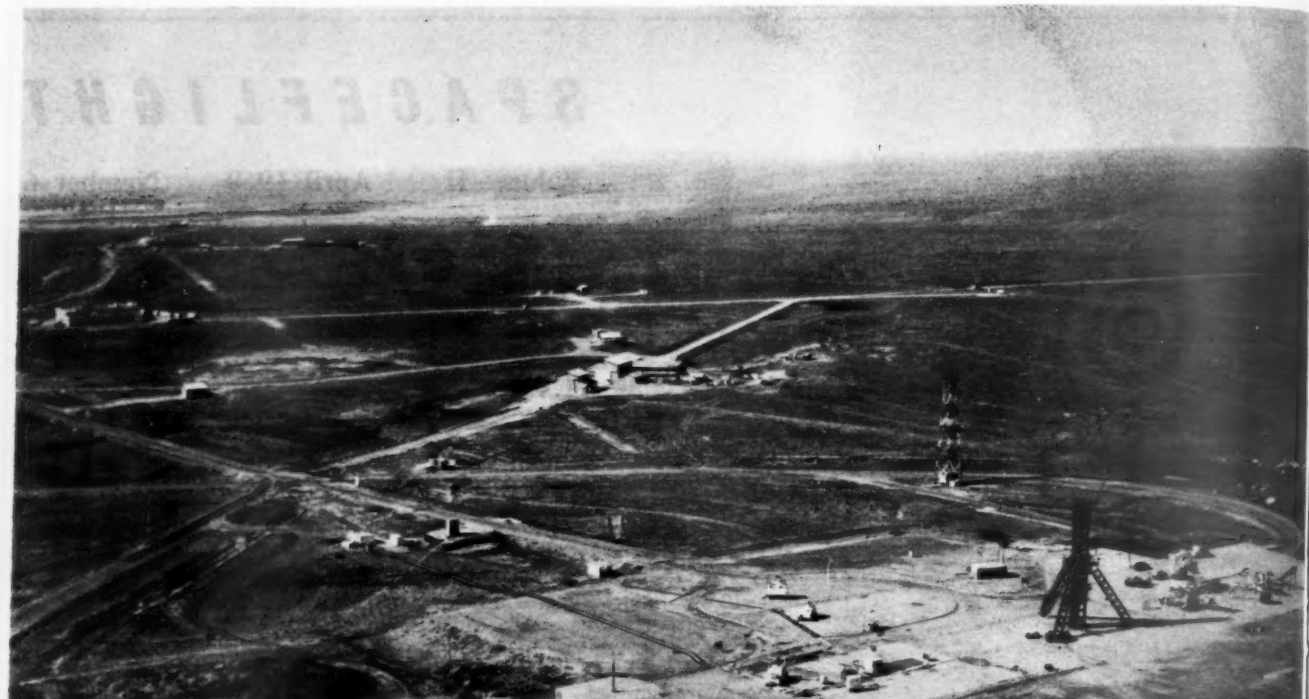


Australian News and Information Bureau

Platform into Space

By Rex Scambary

A remarkable joint effort by defence scientists of Australia and the United Kingdom has converted the arid expanses of Central Australia into one of the World's most advanced ranges for testing rockets and guided-missiles. Whether or not it will also be used for the peaceful development of astronautics—for launching artificial satellites and other space-vehicles—is still unknown, but this article leaves no doubt about the potential of Woomera and its facilities.

The lonely interior of Australia, once little more than the harsh domain of nomadic aborigines, is rapidly changing its destiny—to become a platform into space. A joint, 12-year effort by the Governments of the United Kingdom and Australia, has brought to the area some of the most advanced facilities in the world for testing guided weapons.

To-day, there is greater than normal expectancy at Woomera, the little rocket town that sprang from nowhere in the "gibber" desert. The time is coming nearer for the test launching of Blue Streak, the first British intermediate range ballistic missile.

Still on the secret list, Blue Streak will be the largest weapon fired from the Woomera range, and the most likely missile in the British armoury to take a satellite into space. Basically, however, Blue Streak is a military weapon, and whether it will be used for a space shot has yet to be decided.

Should the effort be made, it is almost certain that Woomera will be the launching ground.

Woomera was laid out for firings towards the north-west, against the direction of the Earth's rotation, and it would involve a payload penalty for satellite launchings. The range has sometimes been criticized on this score, but the disadvantage is more than offset by the superb facilities which it affords, so costly and difficult to duplicate elsewhere.

Preparations for Blue Streak and other projects have brought steady expansion to Woomera in the past year. At the edge of Lake Hart, a dry salt pan, launching area, buildings and firing installations are under construction. The rockets will be launched from giant concrete "silos" built into 150-ft. high cliffs that border the lake.

From here, the missiles will soar high through the Earth's atmosphere and impact 1250 miles down-range, just inside the north-west coast of Australia. Work is advancing on the impact area settlement, called Talgarno. Apart from the technical buildings, accommodation will be provided for as many as 200 scientists, engineers and supporting staff.

These extensions will make Woomera the longest land range outside the U.S.S.R. If necessary, the range could be extended over the Indian Ocean. The new activity is reflected in the growth of Woomera township and neighbouring settlements, which have increased their permanent population by more than 1000 to 4600 within a year.

Woomera has long been overshadowed by the giant rocket installations of the United States of America and the U.S.S.R. It has yet to become an embarkation point for Earth satellites or missiles with Moon-bound payloads. But this should not be allowed to obscure the solid record of achievement at Woomera, a record that is truly a joint accomplishment of two countries—the United Kingdom and Australia.

The partnership began in 1946, when the British Ministry of Supply was looking for a site within the British Commonwealth to use as a range for testing guided weapons. What was needed was an unpopulated area, reasonably accessible, and with buildings nearby for supporting laboratories, workshops and industry.

Australia offered the best prospects. In a later agreement between the two Governments, Australia undertook to share the cost and build and operate the range system now established at Woomera, and to set up at Salisbury, 300 miles to the south, a centre from which the work could be directed.

It was agreed that the United Kingdom would be responsible for the overall policy of guided weapon development, and would undertake the basic research, supply the various weapon prototypes for trials and handle their subsequent production. To look after the Australian side of these activities, the Australian Department of Supply, in collaboration with the British Ministry of Supply, set up the Weapons Research Establishment, with headquarters at Salisbury.

The Salisbury Establishment, near Adelaide, capital of the State of South Australia, was converted from a war-time explosives factory. Spread over some 6 square miles, it houses research facilities and laboratories for undertaking the vast number of tests demanded by weapon trials. Workshops have also been provided for a number of leading British aircraft and electronics firms which are developing guided weapons systems and components under contract to the British Ministry of Aviation.

The Salisbury establishment includes Edinburgh airfield, a base for the Royal Australian Air Force Trials Unit, which operates pilotless target aircraft and other aerial services at Woomera. It is also the Australian terminal for the Royal Air Force Transport Command ferry service, which brings men and equipment from England to Salisbury.

The journey from Salisbury to Woomera is short by Australian standards, but it takes the traveller into a new and strange country. The land is carpeted by "gibber" stones, worn smooth by wind erosion. The main vegetation is saltbush and stunted shrubs, which survive in soil that contains salt concentrations many times as great as sea-water.

The most significant shortage is water. Woomera receives an average of 7 in. of rain a year, but sometimes less than 2 in. Despite this, there is sufficient food to support countless kangaroos and a useful pastoral industry. But it is a hard life for the sheep.

Woomera sits sedately in this landscape, a pleasant town, with neatly laid-out streets and comfortable, single-storey houses, at low rentals. The town has experienced a mild building boom that has given it an appearance of permanence.

Modern, two-storey blocks of flats for married couples, and quarters for single men, were recently completed. Other buildings planned include a new wing to the school, a new kindergarten, assembly hall, mess and recreation centre. Perhaps the most noticeable thing about Woomera is its trees—50,000 of them.

The trees were planted by the Australian Department of Works, which established an arboretum at Woomera

A de Havilland Propellers Blue Streak in a test-tower at Hatfield. After static test-firing at Spadeadam in Cumberland, the rockets will be despatched to Woomera.

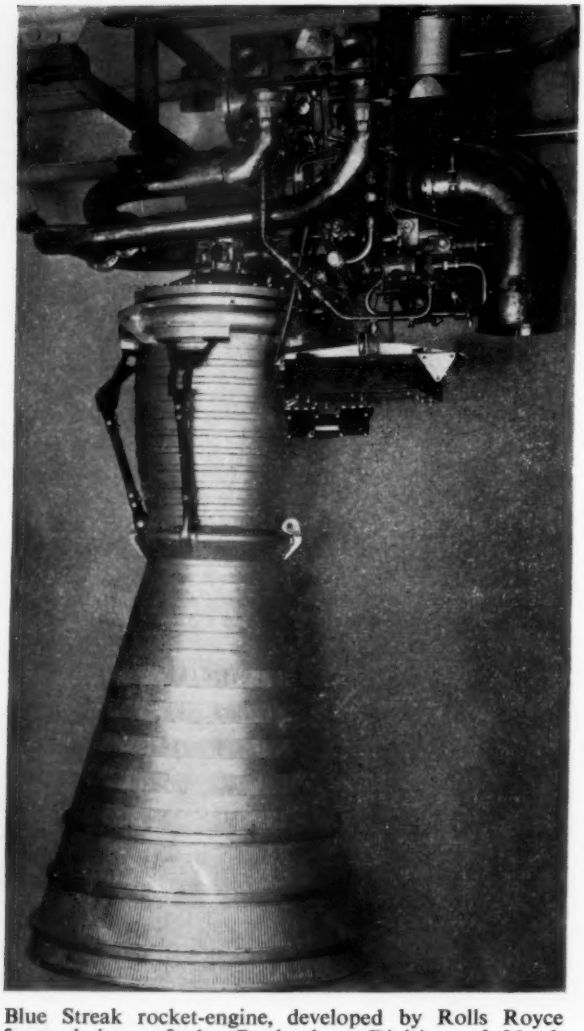
de Havilland Propellers, Ltd.

to see what could be done to make the desert bloom—at least for the sake of appearance. Each tree is separately irrigated through a specially-designed asbestos cement pipe, set at its base. Effluent from the town's sewerage treatment plant is used to conserve water.

Some of the trees are now well above shoulder height, and eventually, Woomera will wear a mantle of green. The same system has been used to grow grass on the main playing field. The other fields have a bare clay surface but this does not deter the local football enthusiasts.

Water is a sensitive matter for householders. The supply is brought 400 miles by pipeline from the River Murray, in South Australia. The pipeline has a maximum capacity of 5,000,000 gallons a week.

Woomera has a community life that does not differ markedly from that of other small Australian towns. When the residents get together, the conversation is more likely to centre on the cost of living, or sport, as the launching of a new missile.



Blue Streak rocket-engine, developed by Rolls Royce from designs of the Rocketdyne Division of North American Aviation, Inc. Twin units are used in the British missile.

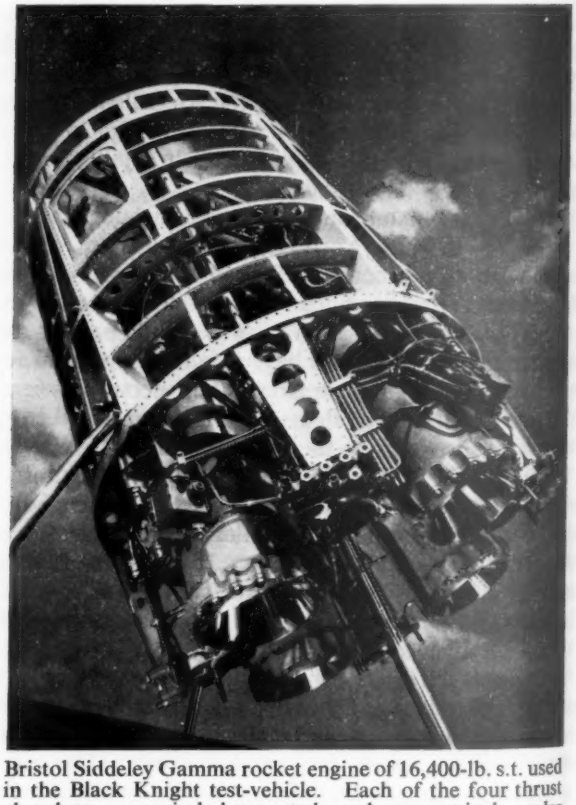
Rolls Royce, Ltd.

"Many people think that this is an isolated place," one resident, a security officer, told me. "Well, possibly it is isolated, but there are so many things to do here that you don't notice it. There's a club for almost every sport you could imagine, we have our own cinemas and, of course, there are a lot of interesting things happening around you. I used to live in Melbourne, but give me Woomera."

Woomera, in fact, has most of the things that a modern small town would require—an excellent community store under Army Canteen Service management, fine churches, a swimming pool, schools and kindergarten. It even has a local newspaper, called "Gibber Gabber," and a Town Board, giving the residents a say in the management of the settlement. The difference between it and other towns is the tight security surrounding it and extending into the long, barren, plains that stretch to the horizon. Out there, remarkable things are happening.

The main missile testing range at Woomera, and the associated ranges, stretch from an area about 25 miles outside of Woomera. The installations are widely dispersed, and the visitor who expects to see a spectacular concentration of launching platforms and rockets being prepared for take off is disappointed.

The conduct of a trial might extend over many miles, and for this a co-ordinated system of instrumentation is deployed down the range. The necessary equipment



Bristol Siddeley Gamma rocket engine of 16,400-lb. s.t. used in the Black Knight test-vehicle. Each of the four thrust chambers are gimbal-mounted and can swivel under hydraulic actuation to provide vehicle stability and control.

Bristol Siddeley Engines, Ltd.

includes various forms of telemetry and internal recorders in the missiles, and ground-based optical and radio tracking and velocity measuring equipment. It is very complex, because as many as 50,000 measurements might be required from a single rocket trial.

The equipment enables scientists to keep a detailed track of events occurring within the missile during flight, its response to the manipulation of its guidance and control systems, its trajectory, the performance of its homing system, and other factors. Because Woomera is a land range, scientists can recover the missile in special cases without serious damage, an important aid in the diagnosis of its behaviour.

From this optical and electronic equipment, a large quantity of magnetic tape, film and paper is accumulated on which details of the trials are recorded. A data reduction system has been developed by the Weapons Research Establishment, based upon a large digital computor called WREDAC, which processes the data at high speed. Where possible, records are made on magnetic tape and fed directly into the processing system.

The main concentration of instruments at Woomera is housed in a central technical building at the head of the range, from where all operations can be synchronized. The system, largely developed by Australian scientists, enables the speed, height and location of a missile to be determined at all times and places the control of these factors as far as possible at the disposal of the trials controller.

Pilotless, target planes are used for trials with anti-aircraft missiles, such as Bristol Bloodhounds. The most renowned is the Jindivik, developed by the Australian Government Aircraft factory at Melbourne, early in the trials programme.

The project called for a target capable of simulating a hostile aircraft flying at extreme altitude. As only some of the trials would require the aircraft to be knocked out by the missile, the target had to have a fairly high recoverability. The Jindivik, of which more sophisticated models have been developed, performs the role admirably, and its cost is comparatively small. Pilotless Canberras and Meteor jets, much larger than the Jindivik, are also used as target aircraft.

A novel camera, developed by Australian scientists and carried in streamlined pods attached to the wing-tips of the Jindivik, photographs the missile as it passes. This enables the "miss-distance" between the target and the missile to be measured. Because the missile can approach the target from any direction, the lenses have been designed with an angle of view of 210 degrees. Since the whole sphere of space comes within the field of view of two such lenses oppositely directed, two cameras only are needed on each wing-tip.

The weapons trials at Woomera reflect the growing strength of the British missile armoury, which includes:—

Bloodhound: A ground-to-air weapon developed jointly by the British Aeroplane Company and Ferranti Ltd., which has been selected as the key weapon in the air defence of the United Kingdom. It will seek out, and home on to, a target held in the beam of ground radar. Acceptance trials of a new version of the Bloodhound are now nearing completion at Woomera.

Night scene at Woomera with a Saunders-Roe Black Knight on the launching stand.

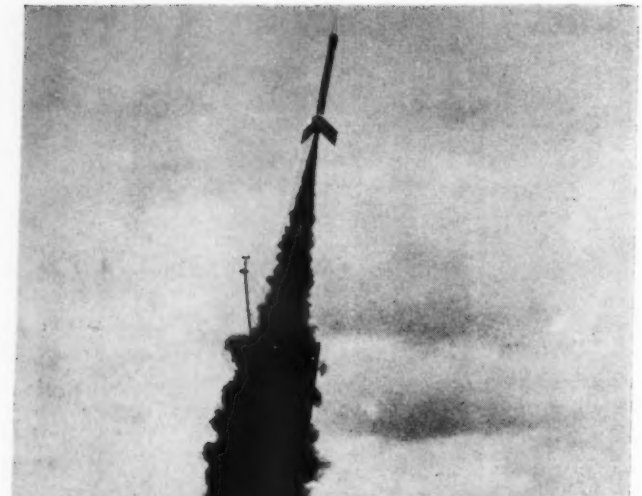
Australian News and Information Bureau

Fireflash: An air-to-air guided weapon developed by the Fairy Aviation Company. Described as a beam-riding weapon, it follows a radar beam which the attacking aircraft directs at the target aircraft. Propulsion is provided by boost "motors" which fall away when expended, allowing the weapon to coast to the target.

Firestreak: An air-to-air guided weapon developed by the de Havilland Aircraft Company. It carries a detector eye which is sensitive to infra-red rays emitted by the air target, and will steer a course towards the source of the radiation.

Seaslug: A ship-to-air guided weapon developed by W. G. Armstrong Whitworth Aircraft Ltd., for use by the Royal Navy. The missiles are fired from a triple-ramp launcher on a ship. Targets are detected and selected by radar.

Black Knight: A highly successful ballistic research rocket, designed by a team headed by the Royal Aircraft Establishment of the British Ministry of Supply. It is about 35 ft. long and 3 ft. in diameter. Black Knight is the largest missile to be tested at Woomera. Five of these research vehicles have already been fired from the range to heights up to 500 miles.



Skylark launching at Woomera.
Australian News and Information Bureau

Skylark: A research rocket, which has been fired to heights of more than 100 miles above Woomera in upper atmosphere experiments being undertaken on behalf of a group of British universities.

Not all of the missiles under test are British. A notable example is the Australian-designed Malkara anti-tank missile, accepted as standard equipment by the British Army. The Malkara, rated almost 100% accurate, is a short-range, wire controlled, line-of-sight missile, capable of destroying bridges, concrete fortifications and tanks. Signals directing Malkara to its moving target are transmitted by a thumb-control along the wire attached to it.

Experiments have also taken place with two Australian-designed and built sounding rockets. Both have been fired to heights up to 100 miles. One, "Long Tom," reached a speed of 4000 m.p.h. and the other, "Aeolus," 3000 m.p.h. The rockets carry instruments capable of measuring micro-meteorite prevalence and wind patterns at high altitude. The latter result is achieved by radar tracking bundles of aluminium foil, ejected by the rocket.

The construction authority for the many projects associated with Woomera—airfields, launching emplacements, buildings and civil engineering works—is the Australian Department of Works. The task has taken officers of the department into parts of the interior probably never before crossed by Europeans. The vastness of the rocket range is indicated by the recent discovery, by a reconnaissance survey party, of several new ranges of hills. The problems of water and materials supply, of access, and a harsh climate have added to the difficulties inherent in such large construction works.

"It isn't really so difficult if you have the manpower and the tools," a Works official told me. "When you bring men to work in some of these remote places you have to look after them. Food is a big thing. If the men are well fed everything goes happily."

Near Woomera town is a collection of small buildings, where a group of Australian scientists, who are detached from the rest of the Woomera scene, keep watch on American and Russian "hardware" in space. This is one of the most important of a chain of satellite tracking and recording stations around the world.

The apparatus consists of two major items: Minitrack radio tracking equipment supplied by the United States Naval Research Laboratory, and a Baker-Nunn tracking camera, provided by the Smithsonian Institute of the United States of America. They are operated under an agreement between the United States and Australia.

Minitrack records the passage of satellites which transmit radio signals. Apparatus is also provided an

[*Continued on page* 192

The American Baker-Nunn camera used to track Earth-satellites from Woomera.
Australian News and Information Bureau

Discussing the Moon

On 1 December last year, a press conference was held by members of the N.A.S.A. Lunar Explorations Working Group for the purpose of acquainting journalists with latest theory on the nature of the Moon, and its origin, and of outlining the tasks that lie ahead in lunar exploration. The following is an edited transcript of part of the discussion, which we are sure will stimulate some lively correspondence from readers.

Present:

Mr. Herb Rosen, presiding.
Dr. Robert Jastrow, Goddard Space Flight Centre, Chairman of the Lunar Science Group.
Dr. Harold Urey, Scripps Institute of Oceanography, University of California, La Jolla, California.
Dr. Thomas Gold, Cornell University, Ithaca, New York.
Dr. Harrison Brown, California Institute of Technology, Pasadena, California.

Mr. ROSEN: Ladies and gentlemen. I should tell you why we are holding this press conference. It is a rare and fine opportunity that we have presented to us to bring before you people such as Dr. Urey, Dr. Gold, and Dr. Jastrow, to discuss the thing that is really foremost in our minds—that is, the Moon.

This is the reason for holding the press conference. But the reason for bringing them into town is that these gentlemen are members of the N.A.S.A. Lunar Science Group. Yesterday they met with other N.A.S.A. people to discuss the Moon. The reason for this meeting was to explain to the geophysicists and geoscientists that there is a relationship between their problems in the exploration of the Earth and the problems concerned with the exploration of the Moon.

The Lunar Science Group of the National Aeronautics and Space Administration has as one of its most important functions the business of providing N.A.S.A. with close contact with eminent scientists interested in lunar science, and conversely to provide the scientific community with an assured contact with N.A.S.A.

The Group will be an invaluable source of ideas and recommendations as it has been in the past for the continuing lunar sciences programme of the National Aeronautics and Space Administration. It will be able to assist the Office of Space Science in defining scientific objectives, payloads, and support requirements for a sound national scientific lunar programme.

For those of you who are interested in the membership of the Lunar Science Group, it consists of the following: Gordon MacDonald, University of California, Institute of Geophysics, Los Angeles; Harrison Brown, California Institute of Technology, Pasadena; Harold Urey, Scripps Institute of Oceanography, University of California, La Jolla, California; Morris Ewing, Columbia University, New York; A. R. Hibbs, Jet Propulsion Laboratory, Pasadena; Ernest Stuhlinger, A.B.M.A.; Thomas Gold, Cornell University, Ithaca, New York; Bruno Rossi, M.I.T., Cambridge; Frank Press, California Institute of Technology; Joshua Lederberg, Stanford University, Department of Genetics; and the Chairman is Robert Jastrow, of the Goddard Space Flight Centre.

On the platform we have, from my right to left, Dr. Gold, Dr. Jastrow, Dr. Urey, and Dr. Harrison Brown.

Dr. Jastrow will open the conference and give you some highlights of the conference we had yesterday with the geoscientists, and then we will throw the discussion open to you on the floor.

DR. JASTROW: We are very pleased to have the opportunity to talk with you and answer your questions.

With reference to the conference we had yesterday it was sponsored by N.A.S.A. It was held specifically by the Theoretical Division of Goddard. It concerned itself with the problems of lunar research, not the money and management problems but the scientific problems, the questions to which we would like to obtain answers, why we care about the answers, and in yesterday's conference, to a very limited degree, how we propose to go about getting them.

The morning session was devoted to some discussion of the meteorites and their origin. These are small bodies, some small, some large, which fall on the surface of the Earth, and there is good reason for believing that some of them at least come from the Moon. There is a great deal of dispute about this last point. That dispute was interwoven throughout the discussion yesterday.

Dr. Urey in particular discussed his ideas on the origin of the meteorites. I think he would be delighted to talk to you about that point as well as about his very strong interest in the Moon itself.

Following the discussion of the origin of the meteorites and some discussion of their possible relation to lunar matter, Harrison Brown presented the results of an analysis of the distribution of sizes and weights of the meteorites and showed that on a log plot. This distribution was a straight line, with slope 0·77, which when extrapolated to very large masses indicated a yield of major fragments, major meteorites, such as might have produced the Arizona meteor crater, and that which fell in Siberia in 1908, I think.

If I am not mistaken, he mentioned to me at one point that on this extrapolation such large falls were about ten thousand years apart. He may wish to say something about that, or some other aspect of his research.

Harvey Allen was also present and talked to us about some re-entry studies based on his ablation work and related to the ablation of meteorites in the atmosphere.

John O'Keefe talked about the tektites and the general problem of the meteorites.

Gordon MacDonald talked about the interior of the Moon, its thermal history (that is, how hot it was during the course of its lifetime of 4½ billion years or so) and the likelihood of internal seismic activity, moonquakes, etc.

Then there was a discussion by Dr. James Arnold, from Scripps in LaJolla, on the detection of lunar radioactivity, which again, for reasons I hope may come out in this discussion, appears to be one of the most important, if not the most important, first experiment that one might conduct in the vicinity of the Moon.

Finally, Thomas Gold discussed some of the ideas current on the properties of the lunar surface, the nature of the mare, etc.

That concluded the day's session. I think all parties concerned enjoyed it very much. There was a great deal of very loud debate and bitter wrangling which we carefully preserved on tape and hope to be able to have you hear some day, if it is reproducible.

That is all I have to say. I would like to throw it open to the floor.

MR. ROSEN: Are there any questions?

QUESTION: Dr. Jastrow, you said that you discussed questions to which you would like to obtain the answers, and why you would like them. Would you enumerate these for us?

Dr. JASTROW: Yes. Let me ask Harold Urey whether he would first comment on why we would like to have these answers, why we think the Moon is an important object to science.

DR. UREY: People have been interested in the history of the Earth for a long time. It is an interest that concerns a great many people at the present time. People have been much interested in the origin of the solar system, not only the lay interest that we are all acquainted with, but because the development of the solar system is an example of the development of stars, of which there are many.

If one looks around to find places where the record might be preserved, I believe that there are a few places where this record of the history of the solar system is very well preserved in several ways. The Earth is rather bad, but valuable in many ways. It is bad because there is running water on the Earth which has changed the surface of the Earth and given it a very interesting history during the last billion years or so. But this running water has destroyed the more ancient record.

The Moon has had no wear on it at all and hence the events that have occurred on the Moon are still recorded there.

The meteorites are another sample of matter in which a record, a very ancient record, is preserved. We know from them that it is about 4½ billion years since a great many of the processes that produced these objects occurred.

We are fully expecting that the surface regions of the Moon will give us additional information about a very ancient record of the solar system.

And so this in itself will enable us to answer some interesting questions. For example, was the Moon ever completely melted? If it was completely melted, then this requires that we had a very high temperature process a long time ago that produced the Earth. Or if it was not completely melted, was it partially melted, and in what ways was this produced?

Also, I am much interested in it from the standpoint of the abundance of the elements, which the physicists are trying to explain. At our meeting yesterday we practically exhausted all sources of material that was of interest to us, namely the meteorites. No, there are a lot of things to learn about the meteorites, but at least we are feeling the need of additional samples. The Moon will supply this in certain ways, we think.

There are other things. There are the asteroids which should have a well-preserved record as well. But the Moon is nearby, and it has no atmosphere, no water. It is cold enough to preserve a great many of the things we wish to investigate, and so this is our first stopping place in our exploration of space.

DR. JASTROW: This question of the origin of the solar system, I hope, does not seem to you to be a dry and very academic one. It is a question of tremendous interest and unexpectedly widespread importance.

There are a couple of ideas that have been current in recent times regarding the origin. One of the popular ones a while ago was that the planets and other bodies in the solar system were torn out of the body of the Sun by gravitational forces in a near collision with another star going by by accident, and that these hot masses of gas condensed in the course of time into the planets and satellites as we know them.

Another theory holds that the Sun itself was formed by the condensation of interstellar gas and as the Sun condensed into a disc and under gravitational attraction to a more compact mass, there was some mass left around the outside of it which in turn condensed into smaller centres, not planets but at least small objects which may have been of planetary size, or even smaller. In the course of time, some of them collided and because large masses attract more strongly than small, there was an instability and accidental fluctuation could produce very large bodies by the secretion process.

The point I want to make is that if the solar system was formed out of hot gas of the Sun, then surely the bodies in the solar system were at one time very hot, and the Moon and Earth as they condensed must have been in melted form before they solidified.

On the other hand, if the condensation occurred out of cool gas by accretion of small objects, then it is very likely that they were never melted unless radioactive elements in the interior raised the melting point. We will also have learned a great deal concerning the probability of life about other stars which is a subject of tremendous philosophical and scientific interest.

The probabilities of collison between two stars is very remote. On the other hand if the solar system was formed by the condensation process it is much more probable that there are planets around a great many stars.

Of those planets, the ones which happen to be of about the size of the Earth and about the right distance from their stars to get the same amount of radiation as the Earth, will have circumstances favourable for the creation of life as we know it.

This is all in the background of this problem of determining the origin of the solar system.

As Harold has said, in that problem the Moon is the most interesting nearby object in the skies for us, because its history has been preserved throughout its life of 3 or 4 billion years.

DR. GOLD: Of course I completely agree with what has been said about the importance of the Moon in understanding the origin of the solar system.

The ideas that one has about how many other solar systems there might be, of course, is very much dependent upon the correct interpretation here. One has reason to believe that perhaps all slowly rotating stars are rotating so slowly because their spin has been lost through friction with a disc of material giving rise to planets; such is one of the more modern theories of the origin of the solar system.

In that case one would think that all slowly rotating stars are stars possessing planetary systems or at least discs of gas that are capable of condensing into planetary systems.

In addition to seeing the details of the geological record embedded in the Moon, of the geological, as it were, lunological, record of the solar system, one might also discover facts about the origin of the solar system from the dynamics of the gas which is still in existence now and which might give us a clue about the gas dynamics that might have been responsible for the actual formation process and the distribution of the momentum in the system.

Would you like me to say something about the Moon?

DR. JASTROW: If you hadn't, I was going to say now let's get to some of the things that we really got enthusiastic about yesterday, namely, what is on the surface of the Moon, how do we think it compares with our old ideas. What do you think?

DR. GOLD: I have been proposing the point of view that the Moon itself has been through most of the history, to which the present features on its surface relate; through most of its history it has been cold or largely cold, cold enough so that no very large changes of internal origin have occurred.

The arguments for this are that we see a lot of markings, as you see on these pictures, of roughly a circular sort.

For example, Tom points out that every one of the markings on this much-scarred surface is an exact circle. You don't find any displacements produced by mountains.

DR. GOLD: When you say an exact circle, it is not that it is precisely circular, but in no way has it shifted, deformed, substantially pulled out of line. If you took any markings that had been put a long time ago on the Earth's surface, and came along a billion years later, there would be very few places on the Earth's surface where there would not have been large contortions of the ground that would have displaced them very greatly.

DR. JASTROW: Isn't it correct that on the Earth such configurations might last about 10 to a 100 million years?

DR. GOLD: Yes.

DR. JASTROW: If not longer. It is a short time.

DR. GOLD: Not only for erosion. Quite apart from erosion, for reasons of internal deformations that are impressed upon the Earth's surface; these deformations are conspicuously absent on the Moon.

DR. JASTROW: That means that everything here is 3 or 4 billion years old.

QUESTION: How do we know that?

DR. GOLD: We have the following reason: We are almost convinced that all the pock-marks that you see are due to impacts with quite large objects. There is no other reasonable way of interpreting the detailed features, and indeed the actual even present-day rate of bombardment on the Earth by substantial pieces would suggest, in any case, a certain fraction to be due to that process. And since they all look much alike, we therefore suppose they are. If they are due to impacts, then at least the bigger ones must be due to impacts that occurred at the time that preceded the bulk of the geological record on the Earth, because otherwise the Earth would show that kind of a surface.

That alone puts it a matter of more than about a billion years ago. Otherwise we would go to the Canadian Shield and we would find it all full of circular holes just as any region, for example, here, would be.

But it isn't. These holes are quite deep. Despite all erosion they would still show in the geology of the ancient regions of the Earth. They are not there. There might be some there but they are not there in this kind of concentration.

So this puts the whole story back; the bulk of this bombardment must have been only about a billion years ago.

DR. UREY: Three billion.

DR. GOLD: In fact one would be inclined to put that date substantially further back. But I think one could really sort of swear that it must have been over a billion years ago, most probably something like three.

QUESTION: What kind of a mark would an object hitting the Moon at an oblique angle leave?

DR. GOLD: It leaves a circular mark, or roughly circular. The point is that objects hitting the surface at a very high speed do not make an impact hole like a bullet would at a much lower speed because the bullet's hole is formed chiefly by pushing the material out of the way by the impact.

At these very high speeds the hole is made not by that process but by the fact that the incoming object is so intensely heated by the collision at this very high speed that it is vaporized and a considerable quantity of ground is vaporized; therefore a large part of the hole is made just from the sudden release of this extremely hot gas, a large quantity of very hot gas that is suddenly released. That makes a circular hole, roughly speaking, a hole whose shape at any rate is not very dependent on the direction at which the piece came in. It is just that at those speeds any solid behaves like an explosive at impact.

QUESTION: What sort of a swarm of material might we have run through a couple of billion years ago to create a situation like that on the Moon?

DR. GOLD: Some of us think that this swarm of material was really part of the material from which the solar system originated; that what you are seeing here is perhaps the tail end of the material to be picked up to form the planets. Some of that very tail end perhaps is still in existence now as meteorites.

QUESTION: And as asteroids also?

DR. GOLD: And as asteroids. There is no doubt that the meteoritic material in the solar system and the asteroid material in the solar system is being depleted because it is still being picked up by planets, undoubtedly in much greater quantity at the moment than it is being shattered off them.

But, of course, one would expect that the final phase of such a process would take a very long time. By the time you have only a few pieces left, comparatively few, it will take a long time to gather them all up.

So sometime in the past the rates, presumably, were higher and were responsible for all this. Some of us think that this is the kind of surface which a body will have on it when it has just been put together from a certain distribution of large and small pieces.

One aim is to interpret the lunar features in this light, and with the great absence of any internal upheaval, with no mountain building process of internal origin but with pock marks being the only surface features, one is very tempted to think—at least I am very tempted to think—that there were no large internal re-melting processes, that there were no large lava flows, no great outpourings of internal material. Because such outpourings of internal material, one would think, would tend to distort all the adjacent regions, distort the ground and buckle it and contort it, as happened on the Earth with much smaller outpourings.

DR. JASTROW: Don't these look like lava?

DR. GOLD: The argument has usually been the following, and this is the one that I oppose: That all the dark regions you see, which are remarkably flat, though not quite flat, that all these regions were caused by flooding by a very fluid lava, fluid enough to distribute itself flat over big distances, and that therefore an enormous amount of volcanic activity must have occurred. This idea, of course, became current at the time when one still thought of the pock-marks themselves as volcanos.

There is so much evidence against this point of view, of the pock-marks being volcanos, that most people accept the point of view that these are impact craters but still hang on to the idea that the flat regions were lava of internal origin.

DR. JASTROW: How about that Russian observation of the parent volcano?

DR. GOLD: I should like to make it clear that we believe that any volcano, any active volcano of a terrestrial sort, of which there are hundreds on the Earth, on the front face of the Moon would have shown up in a way that we would have known about for very many years.

The quantities of gas, ashes, vapours of all sorts that come up from the interior of active volcanos, quite apart from the big eruptions, are so great that they would show up optically quite easily on the Moon.

There is no question that the face of the Moon that we see, and probably not the back, either, contains even the smallest of active "terrestrial" volcanos.

QUESTION: Then you think the Russian observation was in error?

DR. GOLD: I wouldn't say that. But I would say that it is quite possible, and really to be expected, that from time to time some gas will blow out of the interior of the Moon. That is a thing not necessarily related to volcanism. If you put a big object like the Moon into a good vacuum and watch it for a long time, unless it keeps absolutely still, the slightest bit of cracking that occurs, the slightest bit of distortion, will release internal gases, of which there must be plenty locked up on the Moon, and the quantities of gas coming out into this very good vacuum may produce visible results such as the Russians claim to have observed.

But is is quite certain that this was not an outburst in which big floods of lava came out or anything of that kind. It is not like a terrestrial volcano.

QUESTION: Incidentally, Koserov says the outgassing or whatever you call it, is still going on; that he detected some since the original discovery.

DR. JASTROW: We discussed this question at some length in the symposium we had here in Washington last April. The consensus, I think it is fair to say, was that there may have been some outgassing, and this may indeed still be going on.

DR. UREY: I might remark that, if we think a little about what it would be like, the outgassing problem would involve water, if relations to the Earth mean anything at all.

You have almost a perfect vacuum. And so this water would rush out, evaporate and go down to a low temperature and the water would freeze and finally freeze up the hole through which it was coming and it would still evaporate and you would expect that it would partake somewhat of the action of a geyser.

If you think of the geysers of Yellowstone, they have been going on, to my personal knowledge, for 50 years without making much change in the appearance of the geyser at all. And so this sort of thing happening on the Moon would be one that would leave no marks that one would see at all.

DR. JASTROW: With a few exceptions in the highlands the Moon is not the conception of a flat plain with steep craggy peaks towering out of it. It is a broad rolling region. We don't know the structure. We don't know if it consists of broken lava bits or other things.

DR. GOLD: We know something about the fine structure, namely that radar observations have shown that it is remarkably smooth down to dimensions of the order of a few inches. It is not very much rougher on the scale of a few inches than the roughness we see on this kind of scale where we can see about a mile. That is to say, when we see a gradient extending over a distance of a mile here, when you go in detail and look at it, you will find it over that distance of a mile to be pretty smooth, not to be broken up into little ups and downs.

QUESTION: It would be a pebbly or sandy surface?

DR. GOLD: Yes, with the units of it being at any rate smaller than a few inches. It is sure from the radar observation that the surface is not all covered with boulders, shall we say. If we had thought of this being pock-marks blasted out of very hard rock, and with nothing else happening after that, then you would do best to go to Northern Quebec and have a look at the crater which I am almost certain is meteoritic there, and it is about 2 miles across. It is composed of very tough rock with the pieces that were thrown out to make the big bowl, all pieces of this sort of size (indicating). And there is a thousand-foot wall, or something of that order, around this crater, and it is entirely through its whole volume, as far as we can tell, composed of chunks of rock that size, each weighing a matter of 3 or 4 tons.

QUESTION: Is that Chubb Crater?

DR. GOLD: Yes. If all this amount of bombardment had just occurred in hard rock like that, and were not subsequently eroded, then we would expect all this to be as rough as the Chubb Crater is and the radar observations would be completely different. So there is no question that this is not the situation.

I think for this reason and for some others an erosion process must be envisaged as having occurred that works in the way of making things remarkably smooth. I personally think that it goes so far as to make the very large flat regions. So that all this I think of as being sedimented powder.

QUESTION: Without wind and without water, where does your erosion come from?

DR. GOLD: How does the stuff get transported?

DR. JASTROW: One is the mechanism of transport of the fine material, and the other is how it is powdered.

DR. GOLD: One mechanism is the construction of the craters. They are all round, so it is clear they resulted from large impacts. A large proportion, to say the least, of the material will, in any case, have been made into fine powder then. So it may be that the problem as to what makes the fine powder isn't very hard. Almost all that we see might, in fact, be made of very fine powder, loosely cemented together in some places, but not much.

The transportation is the real teaser. It has seemed to me that by far the largest force to be expected to be active in moving any particle on the surface, on the Earth, would be wind and water. On the Moon, in a vacuum, it is likely to be electrostatic forces. I can easily move the dust particles, as on the table here, electrostatically, by electrostatic forces. We have a perfectly good agency in the way of the Sun, in the presence of a vacuum; we have a perfectly good agency for charging in an eratic small-scale pattern the dust particles that lie on the surface. And I think that that provides a way of moving the material by charging it in such a way, eratically, that every now and then some particles jump.

QUESTION: Repel each other?

DR. GOLD: Repel each other and move. So that every particle on the surface suffers a little jump every now and then.

I know that sounds like a slight process, but the time scales we have available are enormously greater than the erosion times available on the Earth, and if one makes estimates they are perfectly reasonable. Indeed, if one makes an experiment, as was done by a graduate student of mine at M.I.T., if one makes experiments with bombardment of rock powders with beams of charged particles, of the same nature as actually come from the Sun and undoubtedly hit the Moon, one can reproduce this method of erratic jumping of grains.

So this kind of hypothesis that the flat regions are all made in that way, and are a denudation of the high ground, is the alternative to the point of view that other people have largely held, that all the flat regions are due to internally-supplied lava.

DR. JASTROW: At the beginning someone asked the question: why do we think it is important to find out about the Moon? We said it is concerned with one of the most fundamental of all problems in human investigation, the origin of our solar system, and that has many ramifications.

Then the gentleman also asked, how do we propose to find out what is there. I wonder whether it might not be interesting to mention a few of the things that we have in mind. Not when we plan to do them, but what we plan to do.

In this connection, there are really two motivations. One is that one wishes to explore the surface of the Moon in great detail to find out if it really is covered with dust as Dr. Gold suggests, and it surely is; and it is only a question of how deep the layer of dust is, and how big the rocks are, and what the fine-scale structure of the surface is so that we can pick good landing sites eventually for depositing packages of remote-controlled instruments. That one would hope to do from a television camera or photographic instrument in a satellite, a lunar satellite. It will take a while to do that and do it well.

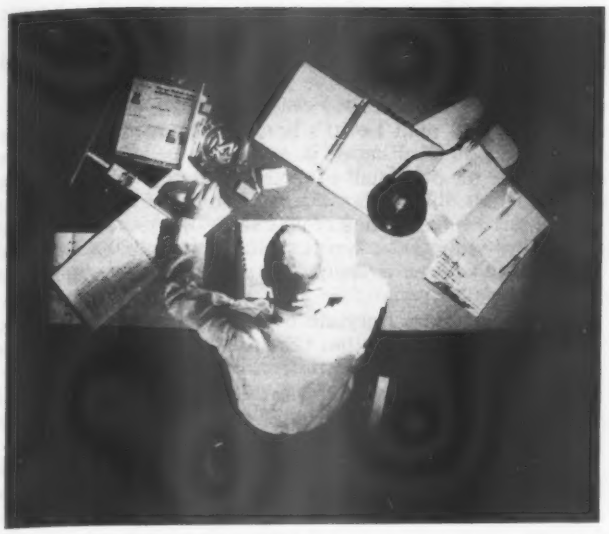
Another point that we want very much to examine, and this is an experiment which is being developed by Dr. Arnold—who is not here, unfortunately—is the detection of the radioactivity in the surface of the Moon. The reasons why that is important are twofold. One in particular. We want to know whether the Moon has ever melted at any time, and what its thermal history is, because that is related to the origin of the solar system. How hot was it at earlier times in its history? That heating is to a large degree contributed by the decays of the radioactive elements, uranium, and so forth, on the surface and in the interior of the Moon. If we can measure the amount of radioactivity on the crust, we will have some idea of the concentration on the Moon and have some idea of its thermal history.

In addition, different kinds of rocks and matter that have been proposed for the surface of the Moon have different amounts of radioactivity in them. So if we measure the gamma-rays which come off radioactive decays, we get some information about the surface composition.

Then finally, cosmic ray neutrons are captured by the surface, as Dr. Arnold and his collaborators have discovered, these produce artificial radioactivity, and the gamma-rays in the resultant decays are again characteristic of the elements on the surface.

So if we can put a gamma-ray lunar detector on the satellite, we can detect something about the surface composition of the Moon before we land there.

QUESTION: Were you able to get any information on the radioactivity from the Soviet Moon shot?



Scientists at the Boeing Airplane Company occupy unique quarters designed for one purpose—thinking. In these "think tanks," members of the company's advanced design section physical sciences group spend their days working on nothing but new concepts and designs for the future. Their efforts are uninterrupted and they are free to initiate research into any problem, "constantly seeking out bridges which will allow them to cross existing plateaus of scientific knowledge."

Boeing Airplane Company

DR. JASTROW: No, I don't think they had an activity detector.

QUESTION: We asked them that at the press conference, and they said they had. They reported 1/100,000 or 1/10,000 of a natural radiation background. Otherwise, their cosmic ray scientist stated they detected nothing with this instrument.

DR. UREY: Let me explain just a little bit about this radioactivity in more detail so that you will get the picture. Constant melting throughout the Earth has been occurring all through its history. This material flows to the surface of the Earth as basalt, granite, and so forth. Uranium and thorium are increased in these materials by a factor of about one hundred or more over that found in the average meteorites, the most numerous group of which are the chrondrites. Potassium is increased in these surface materials by twenty to forty times.

If we turn to another group of meteorites, the achondrites, the uranium and thorium are increased by a factor of about ten over that of the chondrites, but the potassium is decreased.

Suppose that the surface of the Moon has been differentiated by the Earth. Then we expect to find similar amounts of radioactive materials on the Moon's surface. Suppose it has not been differentiated at all. It would probably be similar to some of the chondrites. That is very low concentration. And it might be intermediate if some melting processes similar to those that seemed to have occurred in the case of the achondrites were effective on the Moon. So by just spotting this radioactivity we have a very quick analysis that indicates what kind of differentiation has taken place, and it aids us in understanding the history of the Moon.

QUESTION: Dr. Urey, how much of this observation can be indirect or by inference, and how much actually is reduced to a matter of going there and picking up a piece and bringing it back to analyse it?

DR. UREY: On the score of radioactivity, by flying a vehicle a hundred miles above the surface of the moon, say, or something of that sort, it should be possible to find out whether potassium has increased in concentration on the surface of the Moon or not, and it is entirely possible that the Russian scientists have already made that measurement. We won't say they have, but it is possible that they have.

Now then, understand this would only tell us what is in the very outside surface of the Moon. If there is debris and broken up material scattered all over the surface of the Moon, maybe we are only looking at the debris and therefore we should be sceptical of the result.

If you wish to go farther than that, we must land apparatus on the Moon that pick up samples of the Moon at the surface and down below the surface and at various places on the Moon and make analyses of this kind.

QUESTION: Actually, then, we shall have to do some mining.

DR. UREY: Probably not deep mining, but one would want to dig away a matter of feet, 10 ft. or something of the sort, to get down to see what there is below.

DR. JASTROW: Harrison Brown has an experiment he is interested in, and has been consulting on, the development of which involves the examination of surface samples. Would you say something about that?

DR. BROWN: I just think it should be emphasized that in principle it is possible to send instruments to the Moon which will carry out chemical analyses for you by remote control, and that the resultant analysis can be telemetered back to Earth.

There are many kinds of approaches to this. The radioactivity experiment is one. Another approach which we are using quite successfully on meteorites at the present time is known as X-ray fluorescence, where you put a slab of meteorite under a particular kind of X-ray machine and you measure the radiations that are given off. You can actually determine the relative numbers of atoms of certain critical elements. Were we able to put something like this on the Moon we would be able to get an analysis with respect to these elements and in that way determine something about the chemical nature of the rock which is there.

In like manner, it is possible in principle to carry out another kind of analysis which we call neutron activation analysis, which we have used rather successfully for trace elements in meteorites. This would mean dropping a suitable neutron source on the Moon with suitable detectors measuring the radiations which are emitted.

At the present time there are several of us who are interested in these problems and are working on them.

DR. UREY: May I just mention, continuing what Dr. Brown was saying, that very interesting studies have taken place during the last 10 years due to the efforts of a number of very brilliant young men in this country—in Washington, Chicago, California—and also in the U.S.S.R.—directed toward understanding the ages of these objects by radioactive dating.

One of these methods depends upon the rate at which potassium turns to argon. The maximum date observed so far for stone meteorites, to which this applies, is 4·4 billion years. Since that time such objects have not been warmed above ordinary temperatures, certainly those existing on the Earth, for all that length of time.

We would like to know the same thing about the Moon. Was the Moon made at the same time the meteorites were made?

This date of the meteorites is known. An inference that the Earth was made at the same time is only an inference. We have no measurements that certainly prove this. And the same is true of the Moon. Was the Moon made at this time? Are we indeed dating the actual process of the formation of the solar system in these studies?

Another interesting subject that has been investigated is the existence of certain gaseous materials produced by cosmic rays in the meteorites. This has been investigated in iron meteorites and stone meteorites. The oldest ages so far found by this process run to the billions of years as a maximum,

though most of them are in the neighbourhood of millions of years.

This lower age we think is due to the objects being broken out of a matrix that protected them against the cosmic rays. And the date at which they were broken out is what we think we are measuring.

Curiously enough the stone meteorites are much younger than this on the cosmic ray scale, some tens of millions of years. We are most puzzled as to why this should be.

So far as the Moon is concerned, if we can get a sample from somewhere around the poles of the Moon, not too far below the surface and if we can have a sample of that material, can extract these gasses from it, and measure the quantities, we will be able to say whether cosmic rays are constant in time during the history of the solar system or not. At least we will have a total effect for the life of the Moon, in regard to this problem.

We are much interested in these exceedingly powerful cosmic rays, where they come from, how they are produced, their constances in time. If you wish to go back in time on any of these problems, then a sample of the Moon gives us an opportunity to investigate it.

DR. JASTROW: The interesting thing is that the Moon is more important than Mars and Venus. The Moon is the only object that we have accessible to us which has not been destroyed for us by surface erosion. Mars, Venus and Earth all have an atmosphere, and possibly oceans at one time. But the Moon is the only one that has all of its history written on it. And therefore if we want to know the origin of the solar system it is the Moon that we have to go for. I think that is the basic reason why we as scientists are so interested in the Moon.

QUESTION: I want to ask Dr. Gold about the Soviet Moon photo, if it has given him any new information.

DR. GOLD: I think from the point of view of the studies that I was referring to, one has enough examples on the near surface and one is very desirous, of course, to have a very high definition for that purpose, so that one would concentrate on looking at the best pictures on the front available at the present time.

It is naturally of great interest whether there is any consistent difference between the general type of surface that the front has as compared with the back, and if any photographs of this sort showed any consistent difference between front and back then or course one would have to think again, or indeed if it showed any features which are different in type from any features that occur on the front.

The definition of the Russian pictures is not sufficient to make any case for a substantial general difference between front and back. On the whole they look rather a lot alike.

That, of course, is not to say that the pictures are not very valuable. But for the study of what shaped the surface in the way it did, one is chiefly desirous of very high definition pictures. I regard these pictures as a first step in that direction, quite apart from being the first pictures of the back.

No doubt similar techniques will be used one day to get much higher definition pictures also than we can ever get from the surface of the Earth. Such very high definition pictures will of course go a long way toward establishing which type of interpretation of the lunar features is correct.

QUESTION: Some commentators on the Russian pictures seemed to think that the far side of the Moon was perhaps a little smoother than the near side, where we had been lead to understand, some of us at any rate, that if anything the near side of the Moon ought to be smoother than the back because of the protection afforded to it by the Earth.

DR. GOLD: The protection afforded by the Earth is very little. It is quite negligible one way or another.

We wouldn't expect any big difference. On the other hand we have on the front an erratic distribution of the mare which cover a large part of that surface in a very haphazard way.

If one just considers the statistics of the six major mare areas, then of course it is very probable that the back will be substantially different. So you would not expect that it would just have a similar amount of area of mare and highlands. In fact the suggestion is that there is more highland area and less mare area on the back.

QUESTION: Dr. Levitt of Fels Planetarium suggested that.

DR. UREY: I read Levitt's book and I agree with him in a certain way and disagree in another way. I am sorry we do not have the other half of the Moon here. Mare Imbrium was the result of an enormous collison that occurred on that part of the Moon. Then if you study the mare on the east part of the Moon I think you must conclude that a great deal of the smooth area is intimately related to this collision in Mare Imbrium.

If one took Mare Imbrium off the front side of the Moon, I think we would find that the front and back sides of the Moon would not be vastly different.

And surely if we removed Mare Imbrium and the other big mare that you see there, Mare Serenitatis, I am quite sure that one would find that the two sides are very similar.

You see, if just two chance collisons with the surface of the Moon make this difference, one would say this: I would expect the same collisions on the back as on this side to a first approximation, but I am not terribly surprised if they are not the same. In this case it is entirely understandable that the two hemispheres should be quite different in appearance.

Levitt said this. But he said it was astronomically improbable that these collisions were on the back side. That is the only point I would disagree with. I would say that it was probable that they could be on the back side, but not surprising if they are erratically distributed.

QUESTION: He also said that these maria were produced by, I think, a very fluid lava which was picked up by the impact of these huge objects. Do you subscribe to that theory, Dr. Urey?

DR. UREY: This is an idea that has been current for a long time. I can, in studying this, make out regions of the Moon that look to me as though they might be due to lava flow. Then I can look at other regions and give you very good reasons why I think that lava flows did not occur at these places.

There are arguments both ways. I am very much inclined to the view that Dr. Gold has expressed, namely that much of the smooth area of the Moon was once very finely divided material.

DR. GOLD: And I have argued about this for years and I think we are essentially in agreement with respect to somewhat different views about it.

Urey has felt that the erosion of the high areas of the Moon were to a large degree responsible for the mare. I have thought that the broken up material possibly on the Moon was largely produced by the big collisions that produced the maria.

That is, while recognizing that these things that Dr. Gold talks about are important in the formation of the Moon, I think this other large effect was also of very great importance.

If it were only a matter of slow erosion, one would expect the whole Moon to look the same everywhere. But if it is due to big collisions, then one expects a difference. But as Dr. Gold emphasized in papers he published some years ago, this smooth material, scattered through all of the craters on the south part of the Moon, for example, could all this be due to a hot lava that oozed up inside all these craters and between them and gave this smooth appearance? As he said, it seems very unlikely. In this way he weaned me away from the idea that all these smooth areas are the result of lava.

But I think one must have to be objective about it and ask the question: What is the evidence in regard to the two? I am sufficiently doubtful about it that I would like to have samples of the Moon. And as I have often remarked, if we were completely sure what the Moon is like before we get there, there is no use in going. You might just as well stay on Earth and be happy with our ideas and not worry about the maria any more.

There are many things like this that need to be investigated and we have been discussing, yesterday, many things that might be done in space exploration that would tighten up our ideas and show us that indeed the material is one thing or the other, or a mixture of both, and to what extent such exist on the surface of the Moon.

QUESTION: What do we know about the Moon that we are sure of?

DR. GOLD: We are reasonably sure of this: We see these pictures and we know the shapes of the craters, the heights of the rim, we know the darkness and lightness and colour of the surface, we know that it is particularly colourless, remarkably colourless compared with terrestrial material, we know that it is generally rather dark.

QUESTION: What colour is it?

DR. GOLD: Dark grey or black.

DR. JASTROW: It has a very low reflectivity. That is the point. It reflects only 10% of the light on it. If you had a chunk of rock in front of you from the Moon it would look black in this room, don't you agree?

DR. GOLD: Yes, mostly. The ray material looks lighter grey and the others darker grey.

DR. JASTROW: If you were standing inside one of those craters, of course, the bright parts would be fairly bright, but the dark parts would be pitch black.

DR. UREY: Another thing we know about the surface, for example, is that it is indeed covered with finely divided material At least a very thin skin of finely divided material must be there in order to account for the temperature changes in the Moon as it goes through its night and day.

What is there beneath this very thin layer on the surface? That we do not know.

QUESTION: How thin would that skin be?

DR. UREY: About 2 mm. About $\frac{1}{8}$ in.

DR. GOLD: That is the minimum that has to be there. That is saying nothing about whether it is the same to a great depth.

DR. JASTROW: We also know—and perhaps this is something you would be interested in—we are almost sure the Moon never had life on it. Now it is quite lifeless. We are quite sure in early times it had no life either because it is too small and light to hold an atmosphere; so no life as we know it can have existed.

High-Energy Rocket Engine

First details of the Pratt & Whitney XLR–115

Successful test-firings have recently taken place in the Unites States of a liquid hydrogen rocket engine, the Pratt & Whitney XLR–115, which opens up vast new opportunities for spaceflight. The engine incorporates a novel turbopump cycle which simplifies the engine and increases its efficiency; and according to its designers, there is no technical obstacle which limits the size of hydrogen engines.

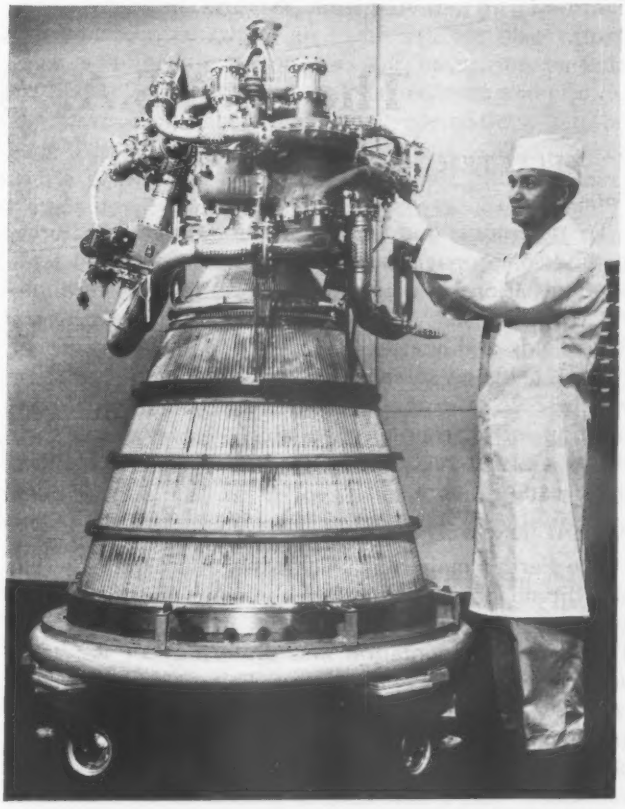
Experimental engines have: (1) Operated for several minutes at a time, starting and running under simulated conditions of space operation; (2) Achieved the rated thrust of 15,000 lb., and (3) Produced a specific impulse* more than 30% greater than current kerosene-fueled rocket engines.

Not only is the XLR-115 the first hydrogen rocket engine to be developed, but it is the first high-performance engine to utilize the so-called "bootstrap" cycle,† which directs all of the fuel through the engine proper.

Most "liquid" rocket engines require that a proportion of their propellents is bypassed and burned in a separate gas generator to provide turbine power so that the propellents can be pumped into the thrust chamber. The XLR-115 eliminates the need for an auxiliary gas generator. Instead, it obtains its pumping power from the expansion of the hydrogen used for cooling the thrust chamber and nozzle.

* The amount of thrust which can be obtained from each pound of propellent in one second of engine operation.

† Actually, the de Havilland Spectre variable-thrust rocket engine, using H_2O_2/kerosene, was the first to operate a self-contained system of this kind.



Pratt and Whitney

The operating cycle is as follows: Liquid hydrogen enters the cooling jacket at −423° F., picks up heat from the thrust chamber and is converted to a gas. The temperature inside the combustion chamber is 5500° F. The hydrogen in the cooling jacket is then expanded in a turbine which furnishes power to pump more liquid hydrogen and liquid oxygen into the system. Thus the fuel plays two roles before it is burned. It drives the

pump system and cools the thrust chamber, and all of it is burned only in the thrust chamber where it produces useful thrust.

The high energy of liquid hydrogen promises substantial payload increases for missiles and space vehicles. Pratt & Whitney estimate that substitution of hydrogen-powered rocket stages for conventional LOX-kerosene stages can multiply the payload as much as three and a half times. Some of the estimated benefits that could result from LOX-hydrogen engines of similar design to the XLR-115 are listed below:

If a hydrogen second stage is added to a current I.C.B.M. it will more than double the payload or increase the range.

The payload of a current two-stage I.C.B.M. can be doubled if the second stage is converted to hydrogen.

Three hydrogen stages will perform the same job as two conventional LOX-kerosene and two hydrogen stages, thereby eliminating one stage.

For placing an artificial satellite in 24-hr. orbit, one that will remain "fixed" in space 22,300 miles above the Earth, the advantages of hydrogen are apparent. Four hydrogen stages would yield a payload more than 3·3 times that possible with four LOX-kerosene stages.

Centaur and Saturn

Development of the XLR-115 was initiated by the U.S. Air Force and is now being directed by the National Aeronautics and Space Administration. In the Centaur space vehicle, the XLR-115 will be used in the second stage on top of a modified Atlas I.C.B.M. The XLR-115 also will power an upper stage of Saturn, the multi-stage space booster planned to launch payloads of 35,000 lb. into a 300-mile orbit or send 12,000 lb. on a deep space mission.

Pratt & Whitney Aircraft and its parent company, United Aircraft Corporation, have used several million gallons of liquid hydrogen in developing the new rocket system. Tests on the XLR-115 have been conducted on a group of four test stands designed for engines of up to 300,000 lb. static thrust.

The N.A.S.A. Space Sciences—3

ELECTRIC AND MAGNETIC FIELDS

Objectives

To determine and understand the origins, natures, methods of propagation, spatial distributions, and temporal variations of magnetic and electric fields throughout the universe. To understand interactions between these fields and matter in space, and the influence of existing fields on solar and planetary atmospheres. To use these fields in the investigation of the internal constitution of astronomical bodies. To evaluate their effects and interactions on instrumented and manned space exploration.

Present Knowledge

The Earth's main magnetic field is approximately that of a dipole located at the Earth's centre, but tilted at an angle of 11 degrees with respect to the Earth's axis. The strength, orientation and uniformity of the main field varies slowly with time. This is called *secular variation*. The field at the Earth's surface is also geographically irregular due to differences in the geology of the Earth's crust. These irregularities are called *anomalies*. On a time scale of months rather than years the above features appear constant at a given location. However, using a time scale of days, hours or minutes, a sensitive instrument shows that the field is practically never constant at any location on the Earth's surface. These variations are usually classified as: *diurnal*—the variations that occur in 24-hr. cycles and appear similar from day to day; *magnetic disturbance*—large variations that are not a daily event in which the field changes are often highly irregular for periods of several or more hours over either small or large areas of the Earth's surface; *magnetic storms*—large variations which occur more or less simultaneously over the entire surface of the Earth; *sudden commencements or impulses*—abrupt changes in the magnetic field which sometimes precede magnetic storms; *pulsations*—sinusoidal oscillations of the magnetic field with wave periods of fractions of a second to 5 min. which frequently persist for one or more hours and sometimes as long as half a day. The magnitude and frequency of occurrence of these variations is a function of geomagnetic latitude. The largest diurnal variation is observed at the magnetic equator. The largest disturbance and storm variations occur in the auroral zones in association with visible auroras. Sudden commencements and impulses tend to be world wide. Pulsations are most prominent in high latitudes and reach their greatest magnitude in the auroral zones.

From the study of surface measurements and from theory it is believed that these variations are caused primarily by electric currents in and above the ionosphere. The currents are attributed to the dynamo action of tides and winds in the ionized gas and to the influx of particles from the Sun. Recent thinking on hydromagnetic phenomena has led some theorists to believe that interactions between the outer portions of the Earth's field and the motion of solar gas clouds also contribute to the variations. It has not, however, been possible to prove any theory or establish an understanding of the phenomena solely from surface measurements. Here lies the importance of direct measurements from space vehicles.

Sensitive magnetometers have been successfully flown into and through the E region. These flights demonstrated the existence of electric currents in the lower

ionosphere at the magnetic equator and in the auroral zones and showed the expected decrease in field intensity with altitude. More than anything else, they showed the need for more measurements.

The magnetic fields of the Sun and other stars have been studied intensively but it cannot be said that there is concrete knowledge of their strength and form. Indirect measurements and theories permit a wide range of possibilities. Galactic field intensities have been estimated from theoretical considerations and the study of light polarization; values between 10^{-3} and 10^{-6} gauss have resulted. Theoretical studies of planetary fields, other than the Earth's, apparently do not exist and methods of indirect measurement have not been found.

An electric field exists between the Earth and its ionosphere, corresponding to an average potential difference of 290,000 volts. There is no direct knowledge of the existence or magnitude of electric fields outside the ionosphere. Theories of the origins and accelerations of auroral particles and cosmic rays allow a wide range of possibilities for interplanetary electric field values.

Existing Problems

The unknowns of most urgent interest are usually those which are most apparent. The most apparent unknowns in magnetic field phenomena are the sources of field variations and the relationships between these variations and other solar-terrestrial phenomena. It is known that some variation is due to ionospheric currents, but the existence, locations and strength of possible electric currents above the ionosphere is not known, even though their existence appears probable. Strictly speaking, the cause of ionospheric currents is not known, and even less is known about probable causes for currents above the ionosphere.

The form of the Earth's main field is at least approximately known close to the Earth, but at distances of 5 to 14 Earth radii, where the field is most effective in guiding solar particles, radical departures from prediction can be expected. The field may expand and contract in response to motions of solar and interplanetary gas clouds. These distortions may in turn propagate as hydromagnetic waves down to the ionosphere and even to the Earth's surface. The possibilities can only be considered speculative until field measurements are made in the outer reaches of the Earth's field.

At some distance the Earth's field will blend with interplanetary and/or interstellar fields. Estimates of interplanetary fields range from 10^{-3} to 10^{-6} gauss. The strength and orientation of these fields is especially important to the understanding of how solar particles reach the Earth.

Theories concerning magnetic fields on other planets are practically non-existent. One reason for this scientific void is probably the lack of understanding of why the Earth has a magnetic field. It is generally thought that the Earth's main field is due to dynamo currents in the liquid core, but the form and cause of these currents is still an open question which may be related to the initial formation of the Earth. This lack of understanding is, however, one of the principal reasons for obtaining measurements of the fields of other planets which formed under different conditions and have a different composition. Similar thoughts suggest that knowledge of the Moon's magnetic field would be a major step toward determining how it formed as an Earth satellite.

Direct measurements of the electric fields exterior to the Earth's ionosphere and in interplanetary space are important to the eventual understanding of how cosmic rays and auroral particles are accelerated and from whence they come.

Programme

Long Range

Results from satellites, probes and rockets to be flown in 1960 will be an important factor in determining the long range programme for studying the Earth's fields. One can, however, anticipate that an important item will be establishing an Earth satellite observatory which will include instruments for measuring particle flux and solar radiations as well as magnetic and electric field instruments such that direct correlations can be made between the various phenomena. Also rocket soundings into the ionosphere will continue to be used to study details of ionospheric currents more thoroughly.

The fields of the Moon, Mars and Venus will first be measured from probes making close approaches and eventually from packages landing and serving as observatories.

Probes will be shot at the Sun to obtain solar field measurements as close to the Sun as feasible.

In all measurements, except the rocket soundings, the experimental intent will be to obtain both the absolute magnitude and the direction of the magnetic field measured. It will be more difficult to separate the ambient electric field from that due to an electric charge on the space craft.

Theoretical analyses and correlations between electric and magnetic field phenomena and other phenomena will be an integral part of the programme.

Immediate

The short-range magnetic field programme includes:

(1) a number of small sounding rockets with proton magnetometers for studying ionospheric currents,

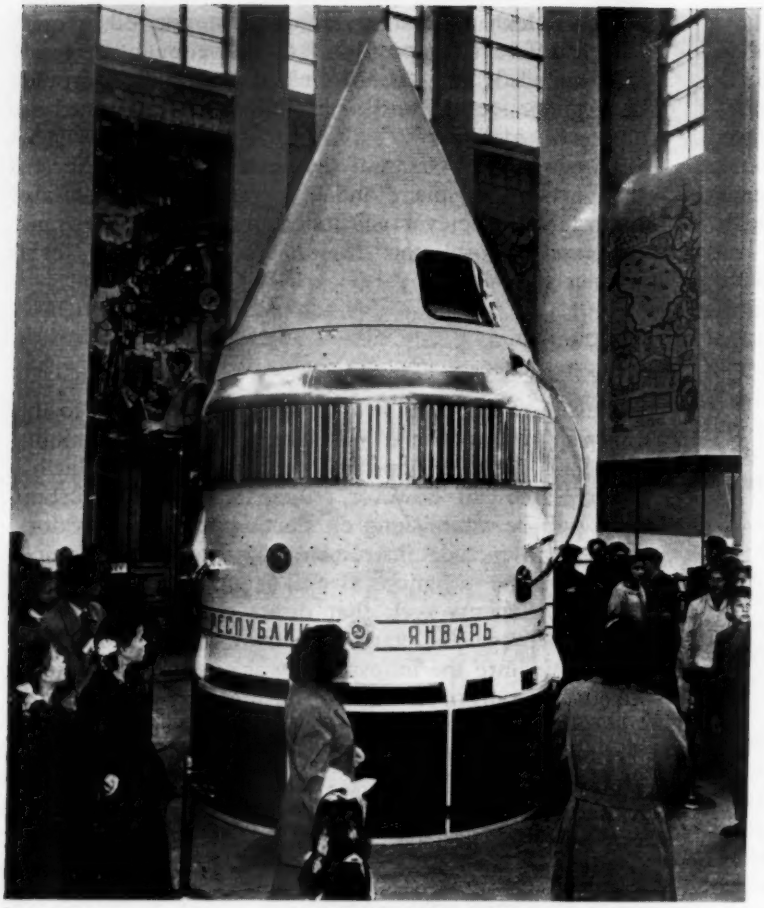
(2) two sounding rockets primarily for flight testing of newly developed Rubidium vapour magnetometers and information on radiation belt currents,

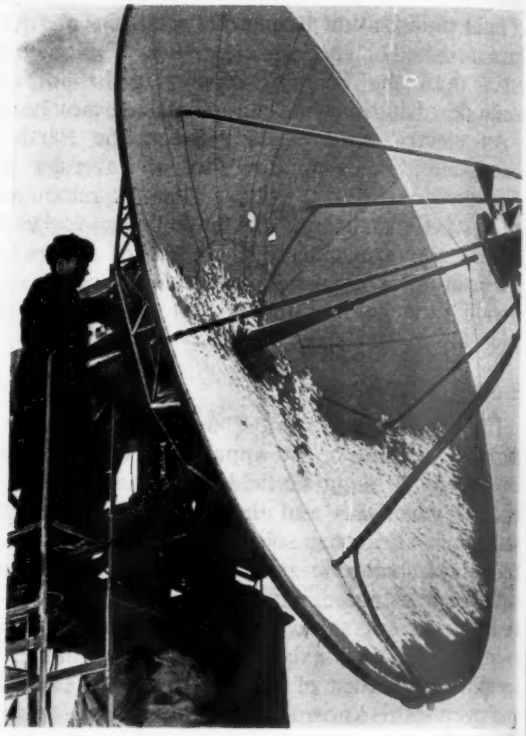
(3) a space probe to the Moon with a Rb-vapour magnetometer for measuring electric currents and the form of the Earth's field at great distances, interplanetary fields, and the Moon's magnetic field.

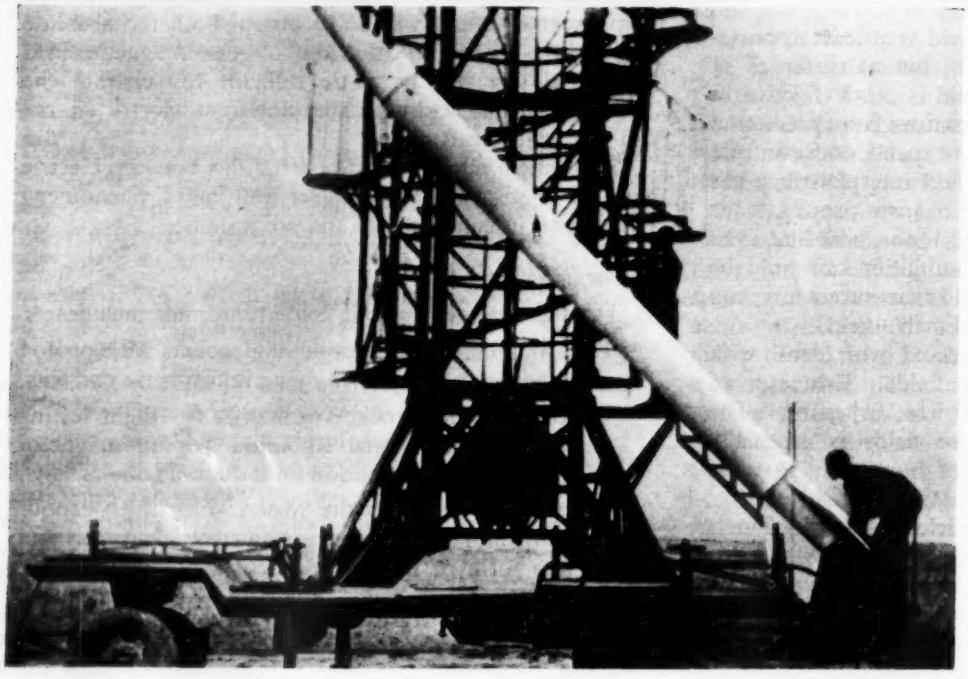
[*Continued on page* 178

SPACE RESEARCH I

These pictures were generously made available to ***SPACEFLIGHT*** *by the Society for Cultural Relations with the U.S.S.R. when Prof. Alla Masevich visited this country in February.*

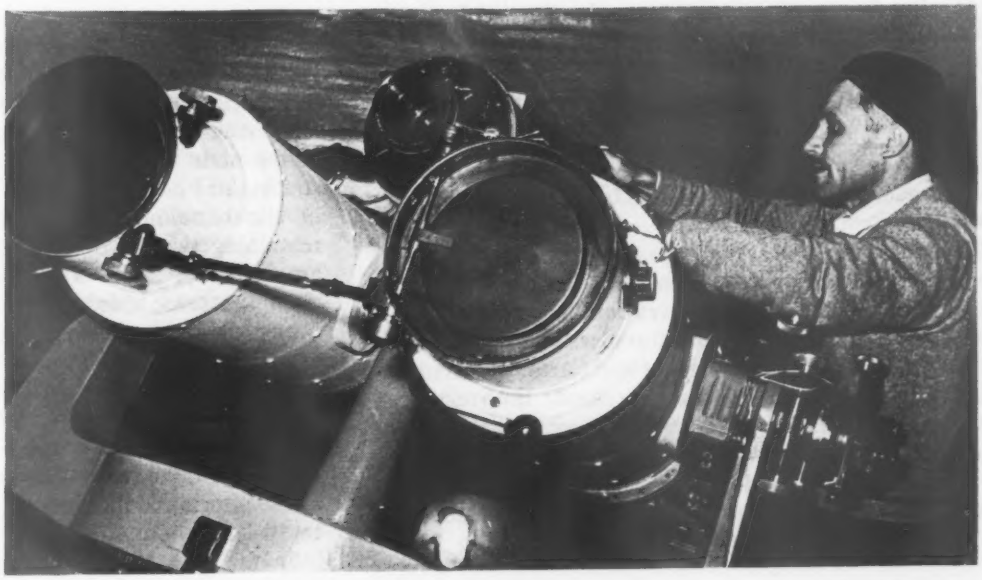


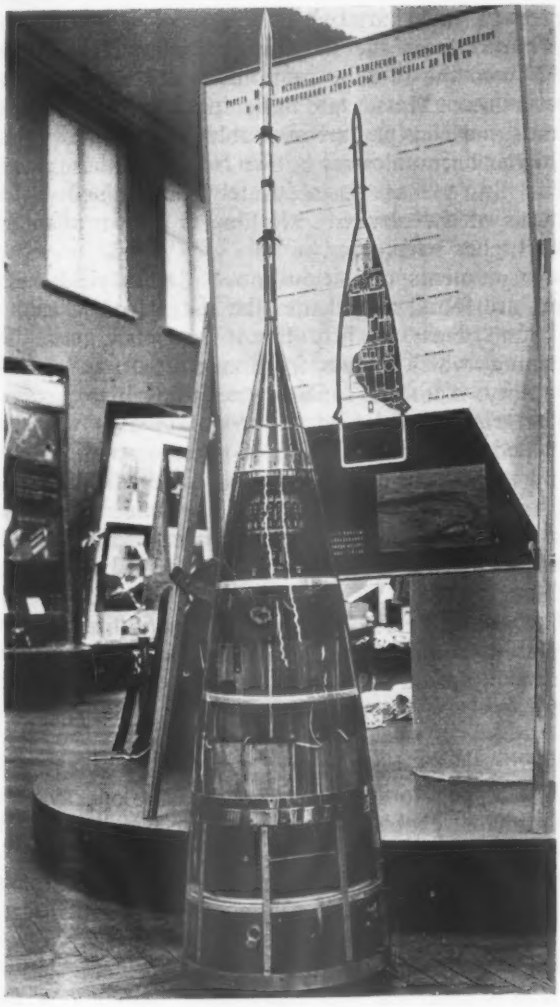




Above, left, full-size reconstruction of the last stage of Lunik I; above, radio-telescope at the Pulkovo Observatory; left, a Russian meteorological rocket being lifted into a launching tower; above, right, camera used to photograph the sodium cloud emitted by Lunik II; right, instrument head of the Russian MR-1 rocket used to measure atmospheric temperature and pressure; and, far right, instrument container of an A-3 geophysical rocket which carried a payload of 3,350-lb. to a height of 294 miles in February, 1958.

IN THE U.S.S.R.





Continued from page 175]

The programme also includes instrument development—the most significant being the development of Rubidium vapour magnetometers by Varian Associates. It is also anticipated that simpler magnetometers which can detect only the existence of a perceptible field will be placed in several rockets and space vehicles as secondary experiments.

GRAVITATIONAL FIELDS

Objectives

To determine and understand the origins, natures, methods of propagation, spatial distributions, temporal variations, and effects of gravitational fields throughout the universe. To determine and understand the external form and internal constitution of the Earth, planets and stars. To determine and understand the relations between gravitational and electromagnetic fields. To evaluate effects of gravitational fields of different magnitudes, including weightlessness, on instrumented and manned space exploration.

Present Knowledge

At the present time, the best theory of the nature of gravitation is Einstein's general theory of relativity, which asserts that the force which we recognize as gravity results from a distortion of space-time. An essential part of this theory is the idea that mass as determined by gravitation will be found to be proportionate to mass as determined by inertia. Other theories have been proposed, especially by George D. Birkhoff.

There are three tests of the general theory of relativity. The first of these is the motion of the perihelion of Mercury, which amounts to 43 sec. of arc per year, agreeing quantitatively with Einstein's prediction. The second is the bending of light in the Sun's gravitational field. It has been measured numerous times, and the results have generally been found to agree with Einstein's predictions; but in view of the smallness of the effect (only 1·75 sec. of arc), there is still room for reasonable doubt about the confirmation.

The third effect is the shift of light toward red wavelengths in a strong gravitational field. This is doubtfully observed in the Sun, where it is confused by mass motions of gases. A red-shift is observed in some white-dwarf stars, but even there it cannot be unequivocally said that this is not an effect of mass motion.

It is further believed that the force of gravity is proportional to the density of matter in the universe. Since the universe is expanding, this means that changes of the order of one part in ten billion per year ought to exist in the force of gravitation.

With respect to the gravitational field of the Earth, this problem would be fully solved if we knew all the harmonics into which the field can be subdivided. There is one zero harmonic which amounts to the product of the gravitational constant by the mass of the Earth, and which has at the present time the value of 3·9868 with an uncertainty amounting to one part in 100,000.

There are three possible first harmonics which arise from the displacement of the centre of the earth from the centre of our present co-ordinate system. This displacement is believed to amount, at the present time, to no more than 100 m. There are five second degree harmonics, of which one harmonic of zero order is intimately related to the flattening of the Earth and has been measured with great precision from the motion of the node of 1958 Beta 2 (Vanguard I). Coefficients so obtained correspond to a flattening of 1/298·3. Two of the remaining four are necessarily zero; and the remaining two have been doubtfully evaluated with an amplitude of about 4 mgals.

Of the seven third degree harmonics, the zonal harmonic of zero order very recently has been measured, and appears to have a value of 5·6 mgals. at the surface of the Earth. The other six have been estimated crudely from gravity data. An estimate of 5 mgals. has been made for the fourth zonal harmonic. It is known that the size of these harmonics is proportional to the stresses at the interior of the Earth roughly at the rate of 1 mgal. to 10 kg./sq. cm.

In the case of Mars, the zero harmonic (the mass) is 0·1076 that of the Earth. Nothing is known with respect to first harmonics. The second harmonic is determined from the flattening which is found to be 1/192 from the satellite motions, and 1/77 from visual observation. Masses and flattenings for Jupiter, Saturn, Uranus and Neptune are available in the same way, but no higher harmonics are known for any of these planets.

The Sun's mass is accurately determined by the motions of the planets. Nothing is known about any other higher harmonics.

Measurements of various double stars yield masses which are found to fall into the range from a tenth of the Sun's mass to fifty times the solar mass. The flattening, which ranges from zero up to the limit of instability, is known for a few eclipsing binary stars.

The gravitational field of the galaxy as a whole has been deduced from the rate of galactic rotation. It is found to be equivalent to several hundred billion solar masses. The gradient of the galactic field which measures the flattening of the galaxy has also been determined from the gradient of galactic rotation near the Sun.

The nature of the intergalactic gravitational field is at present completely unknown; it is not even certain that a repulsion does not exist at sufficiently great distances.

Existing Problems

With respect to the fundamental nature of gravitation, the principal problem is to find some peculiarity of the law which would serve to control the formulation of satisfactory theories. Such a peculiarity might consist, for example, in a small deviation from strict equality of gravitational and inertial mass, or in a velocity of propagation, or in something in the nature of a shielding such as is observed with magnetism. Any one of these

effects would give us a clue to the best direction to look for a more fundamental understanding.

Within the framework of the Newtonian law, the classic problem is that of the long-time stability of a system such as the solar system. The problem may be formulated in this way: As we think of time of the order of 10^9 years, do the orbital planes of the planets tend to approach one another? Do the eccentricities tend to decrease? If so, then, of course, we understand the architecture of our present solar system; if not, then we have an important clue which can someday be used to discover how it was initially formed. The problem of the stability of the solar system has engaged some of the best mathematicians since the days of Lagrange and Laplace, who found that stability could be guaranteed for times of the order of 10^8 years.

With respect to the gravitational fields of the planets, one problem is that of the presence of iron cores in the planets. At the present time, the large density (approximately 5) found for Mercury indicates a large iron core. It is hard to put this in an orderly relation with the density of Mars (about 3·9) and the Moon (about 3·3). In particular, if correct, this density means that the iron core found in some planets cannot represent a pressure modification of ordinary silicate rock. A second test of the pressure modification idea is furnished by the density of Venus, which is just at the critical level. In both cases, it appears possible that further observational data would reverse the conclusions which have been drawn.

The gravitational field of the Earth is closely related to a series of interesting problems. In the first place, the zero harmonic is essential for the study of space trajectories. Next, the internal constitution of the earth manifests itself through variations in the higher harmonics. In particular, a state of hydrostatic equilibrium in the interior of the Earth demands the value of 1/297·3 for the flattening of the Earth. The discrepancy between this and the observed value of 1/298·3 is a major problem in the structure of the Earth. If the discrepancy is due to mechanical strength in the interior, then it may be related to the observed large values of some of the higher harmonics.

At the present time, two independent and contradictory theories have been offered for the inner structure of the Earth and for the formation of mountain ranges. The first of these, which we might call the plastic theory, envisions a viscous interior in which slow convection currents of a few centimetres per year exist, and mountain ranges, such as those around the Pacific, are formed as the result of drag on the underside of the continents. The other theory, which we may call a crystalline theory, considers that the Earth is slowly contracting as it cools, and attributes the formation of mountains to crumpling. At the surface of the earth, the problem of verifying or disproving the "basic hypothesis of geodesy," namely that the product of gravity anomalies in milligals times areas in square kilometres, does not exceed 30 for any extensive patches, is one of the most important that can be set up.

Programme

Long Range

For the study of the fundamental nature of the gravitational field, two avenues are opened by our ability to launch satellites and space probes. The first of these is the ability to try experiments on a scale of hundreds and thousands of kilometres by probing the fields of planetary masses with bodies capable of being accurately observed. This is significant because gravitational fields, except that of the Earth, are almost unmeasurable in laboratory-scale experiments. In the second place, the periods of artificial satellites are so much shorter than those of the Moon and other natural satellites that we can observe in a few years a number of revolutions corresponding to thousands of years for natural satellites. By the first avenue, we hope to find the links which must exist between the theory of the electromagnetic field and the gravitational field. It is planned in particular to test the equality of gravitational and inertial masses by experiments in space on a colossal scale, which are a repetition of the experiment of Galileo in the Leaning Tower of Pisa. An attempt will be made to devise experiments which will reveal the velocity of propagation of gravitation, if any.

It is planned to determine the masses of the inner planets by direct observation of probes passing near them or possibly around them. These probes will at the same time help to determine the value of the astronomical unit, the fundamental meter stick of the solar system.

It is planned to test the hypothesis that gravitational attraction depends on the average density of matter in the universe and that it therefore is slowly weakening as the universe expands. For this purpose, an atomic clock on the ground can be compared with a gravitational clock of some kind. A proposal for a gravitational clock consisting, in effect, of a high satellite with a very well measured orbit is being studied.

It is planned to employ Moon probes to obtain improved values for the overall mass of the Moon and for the moments of inertia about its three principal axes. A determination of the strength of the materials in the Moon's interior will be attempted from this information.

It is planned to measure the mass of Venus and of Mercury in order to test Bullen's idea about the nature of the cores of the planets.

Using the second avenue, it is planned to observe the motions of close satellites of the Earth over a long period and to make a precise comparison with theory, searching for systematic trends in the inclination and the eccentricity, which might shed light on the history of the solar system.

Immediate

(1) Studies are now being made on existing satellites with the object of determining the low harmonics of the Earth's field from tracking data.

(2) Preparations are made for equipment for a special geodetic satellite which will be capable of refining the observations on the harmonics, and of determining intercontinental distances with high precision. It will clearly be possible to carry the study of the form of the geoid much further than has been possible to date.

The information developed in (1) and (2) above will be applied to the question of the basic hypothesis of geodesy. This hypothesis, as formulated by some theorists, is in essence that the low harmonics of the Earth's gravitational field have amplitudes of a meter or so. The hypothesis is not universally accepted; other theorists consider that the amplitudes are of the order of scores of metres. A decision between these two hypotheses is important because Heiskanen, in particular, proposes extensive work based on Stokes' theorem—work which is only warranted if the basic hypothesis is satisfied. This information will also be used in an attempt to evaluate hypotheses of convection in the mantle. These hypotheses seem to go with the ideas of the first-mentioned school of theorists, and it may be possible to decide between these hypotheses and the alternative contraction hypotheses on the basis of our information.

(3) It is planned to put in orbit a satellite carrying a very precise clock in order to test a theory of Einstein which predicts a change in the clock's speed with a change in the strength of the Earth's gravitational potential. If successful, this would constitute a new test of the general theory of relativity, and so improve our understanding of the nature of the Earth's gravitational field.

[*To be continued*

Atomic Batteries

The early use of atomic batteries as a reliable source of electric power ensuring a greater radio range during spaceflights is predicted by Prof. Vladimir Siforov, a prominent Soviet specialist in radio engineering and electronics, writing in *Sovietskaya Kultura*.

He says that scientists have developed semiconductor atomic batteries, based on the ability of some radioactive isotopes, and particularly strontium 90, to produce a strong electron flow, unaccompanied by gamma radiation.

Professor Siforov writes that the electrons emitted by the strontium breed with amazing speed when passing through an isotope-coated semiconductor: one isotope electron multiplies into 200,000 new electrons.

"This gives rise," he says, "to an electric current, though it is true that it is of a rather insignificant value and very low voltage.

"However, we can obtain quite a strong current by joining together several of these 'micro-accumulators.'"

Professor Siforov stresses the useful role which atomic batteries can play in long spaceflights, and especially flights to Mars and Venus.

Does Life Exist in Space?

A number of Soviet scientists headed by Professor Nikolai Zhukov-Verezhnikov, member of the Soviet Academy of Medical Sciences, have come to the conclusion that the time is now ripe for discovering by experiment whether outer space is sterile, that is to say, free from micro-organisms.

In an article published in the newspaper *Meditsinsky Rabotnik* ("Medical Worker"), they propose a programme of research in which the main emphasis is laid on obtaining space material from outside the Earth's atmosphere for chemical and biological analysis.

Professor Zhukov-Verezhnikov and his colleagues believe that the implementation of this programme will settle experimentally the dispute between the two schools of modern microbiology—the Michurin and Weismann-Morgan schools.

"If one abides by the Weismann-Morgan theory," the article says, "it has to be recognized that the chemical composition of micro-organisms on other planets should differ basically from the chemical composition of protein and nucleic acids in terrestrial micro-organisms, because fortuitous changes could not produce a homogeneous structure.

"According to Michurinist conceptions, the structure will be basically similar, inasmuch as the laws governing living matter are the same for the Earth and the other planets."

The scientists say that this question can be solved only when it has been first established by experiment whether there is movement of living spores from one planet to another.

They note that while the influence of space factors on physiological functions can be studied on animals, it is only by sending micro-organisms into outer space that we can determine the limits of the viability of cells and genetic changes.

International Co-operation

In an article in the newspaper *Literaturnaya Gazeta*, written in connection with the second anniversary of the launching of Sputnik I, Nikolai Varvarov stresses the need for international co-operation to tackle the problems of space travel.

Varvarov, who is chairman of the astronautics division of the Voluntary Society for Assisting the Army, Air Force and Navy, writes that "the time is not far off when the first explorers will land on Mars and Venus."

He advocates that expeditions consisting of a number of spaceships, rather than individual spaceships, should be sent on journeys of this magnitude and argues that the preparation and realization of flights to Mars, Venus and other planets will inevitably involve tremendous expense and will require the pooling, not only of scientific effort but also of the material resources of various countries.

Academy of Astronautics

The following notes have been supplied by Mr. N. H. Engelhard with the object of initiating discussion on the proposed Academy of Astronautics, which was the subject of a resolution at the 10th I.A.F. Congress.

Although the type of organization the promoters of the Academy of Astronautics have in mind is unknown to me, I have obtained two views from members of the executive of the B.I.S. One is that the study of astronautics should be given academic dignity by having a centre where qualified people perform useful theoretical work. The other thinks in terms of a small number of leading scientists to exert influence on Governments and peoples and to publish papers or hold meetings.

Both views were advanced by leading members of the Society and, therefore, it is with some trepidation that I dare to comment on them and even to go further by submitting some proposals of my own.

Briefly, these are my views:

(1) The Academy of Astronautics could be expected to do useful work if the facilities and funds available could be compared favourably with those of existing institutions. Would the aim of influencing Governments and peoples not run parallel with and overlap, the work that the I.A.F. and it's constituent members aspire to do?

(2) I suggest as the foremost task of the Academy of Astronautics the spreading of enthusiasm for space travel on a truly practical international footing.

(3) In a similar manner as "the old school tie" forms a link from the oldest to the youngest boy, so the Academy of Astronautics should form a link right round the world encompassing those who are proficient in intricate calculus, or plasma propulsion, or have medical qualifications, or are skilled technicians and artisans, and those (possibly in the not too far future) who train to hold certificates as eligible astronauts.

(4) Neither place of residence, nor language of tutor or student, should form an obstacle to full participation in the work of the Academy of Astronautics. To locate it in one place, or even to share it out between several, would favour the country and language of siting.

(5) It is therefore suggested that the Academy of Astronautics be developed as a "Correspondence Academy."

(6) This tentative term does not mean that it should be a Correspondence School, but that it should be an organization based on contacts by letters. Only the secretarial offices would need location.

(7) This principle would permit the Academy of Astronautics to function at the highest quality level, while running at minimum expense. It would be easy to cover all relevant subjects and the language problem would be reduced to manageable size.

(8) The I.A.F. would nominate the Governing Body of top ranking scientists, irrespective of their addresses and engagements, as the Academy of Astronautics would not require their full time services.

(9) While, at the initial stage, meetings of the Governing Body might speed matters, these would not be essential, certainly not for the normal routine running.

(10) The main task of the Governing Body would be to establish the faculties and appoint the appropriate Training Supervisors.

(11) The Training Supervisors would be drawn from the same ranks as the Governing Body and under the same conditions; the services of the Training Supervisors would not be needed full time.

(12) Thus, it can be expected that a dignified body of highest academic standing can be collected around the World's leading authorities, against minimum expense (nominal fee plus expenses).

(13) The main task of the Training Supervisors would be to investigate existing teaching facilities and determine which come up to the standards set by the Academy of Astronautics.

(14) It might be considered as a later feature to add to the Academy of Astronautics a branch catering for additional tuition where and when necessary, *e.g.*, short time intensive courses, postal teaching.

(15) In time industrial enterprises, scientific institutions, etc., will learn to appreciate the value of the degrees of the Academy of Astronautics.

(16) Many students would find that courses they are taking are recognized by the Academy of Astronautics, and will be encouraged to register with the Academy of Astronautics.

(17) The Academy would keep in touch with the university of the student, supervise and advise him on his training. Finally, existing examinations might come up to the Academy's standard —possibly augmented by additional papers set by the Academy of Astronautics.

(18) Thus, many students will appreciate the possibility of obtaining a degree from the Academy of Astronautics, without undue additional effort.

(19) Further, many post graduates in working life might become interested in taking some additional courses which would qualify them for a degree from the Academy of Astronautics.

(20) The Secretarial Offices of the Academy of Astronautics would be the clearing-house through which all letters flow and all organizational work is carried out. An energetic and enthusiastic secretary with his staff and a team of translators (the latter need not necessarily be on the premises) could form all links and carry all routine work.

(21) This plan claims two major advantages over the other orthodox types of organization for an academy. It would put all participants on an equal footing in a truly practical international way. It would help to spread interest in astronautics. It could do both on a grand scale at minimum expense.—N. H. Engelhard.

Space-Ferry

A piloted "space-ferry," designed to shuttle men and materials back and forth between the Earth and an orbiting space station, has been proposed to the U.S. Government by Lockheed and Hughes Aircraft.

According to its designers, the "space ferry" could carry up to four astronauts—a pilot and three passengers—and about 14,000 lb. of supplies and materials. A typical rendezvous mission with a space station could be accomplished in two to ten orbits over a period of 3 to 12 hr.

Launching would be accomplished by a three-stage rocket with a gross weight of approximately 1,000,000 lb. programmed for automatic guidance throughout the three propulsion stages. On arrival in space near its target station, the vehicle would unfold from the initial symmetrical arrowhead configuration into a flying wing under pilot control.

Pilot, passengers and cargo would be housed in a central cylindrical cabin. Pilot control would be applied by means of reaction jets spaced along the wing and internally-housed electrically-driven inertia wheels.

Using special optical and/or radar homing devices, the pilot would close with the target space station. Passengers, in space suits, could then pass through an airlock or simply step from the ferry to an external platform.

To permit the difficult return through the Earth's atmosphere to land, the planned space-ferry is manoeuvrable and controllable during re-entry. Advanced materials and structural concepts have been used by Lockheed engineers to overcome extreme temperatures up to 2500° F.

A unique automatic system would control extreme temperatures during descent and smooth out the flight path to a relatively gentle glide approach. Landing would be accomplished conventionally at speeds below those of existing airliners.

Model of the proposed Lockheed/Hughes winged re-entry vehicle.

Lockheed Aircraft Corp

The entire design approach involves maximum use of a human pilot, Lockheed's emphasize. "This approach leads to a less complicated and more reliable design. Although fully automatic equipment is used for more critical phases of the mission, the pilot can take control of the vehicle through a manual override in case of emergency, thereby giving greater assurance of safe return of the craft to earth."

Although designed as a "space ferry," for the construction and maintenance of space stations, the vehicle could undertake a variety of missions. It could be used to track and inspect unidentified objects in space; as a "space sweeper" to remove derelicts from "spacelanes"; as a space systems laboratory testing and training facility; and to perform short-term scientific missions on an "excursion" basis.

The New Russian Space-Rocket

We publish below the text of the announcement released by the *Tass* news agency, together with comment by leading Soviet authorities.

A new multi-stage rocket was launched from the Soviet Union nearly 7770 miles into the Central Pacific Ocean on 20 January.

It was the first in a series of launchings* aimed at testing a more powerful, multi-stage, vehicle "for putting heavy Earth-satellites into orbit and for carrying our space-flights towards the planets of the Solar System."

Giving details of the initial firing, *Tass* reported as follows:

"At 8.5 p.m. (Moscow time) on 20 January, the rocket's penultimate stage, together with the nose cone simulating the last stage, moving along the set course and developing a speed of over 16,150 m.p.h., reached the target area in the Pacific some 12,500 miles from the launching site.

"Having fulfilled its task, the penultimate stage of the rocket entered the dense layers of the atmosphere at an altitude of 50 to 56 miles and subsequently disintegrated and partially burned up.

"The nose cone of the last stage of the rocket, which was designed to pass through the dense layers of the atmosphere, reached the surface of the water near the predetermined point of its fall.

"Special Soviet ships stationed in the area where the rocket was expected to fall made valuable telemetric measurements of the flight trajectory as the rocket came down.

Re-entry

"The nose cone of the last stage of the rocket was tracked during its flight in the atmosphere and its contact with the water was recorded by the ships' radar and optical and acoustic installations.

"As a result of the measurements it was established that the rocket fell less than 1¼ miles away from the predetermined point, which confirms the high degree of accuracy of the rocket's guidance system.

"The rocket was launched sharp on the appointed time. The flight of the rocket as a whole and the functioning of all its stages corresponded with the programme outlined.

"Throughout the entire flight, the measuring systems and devices installed in the rocket ensured the transmission of essential data to installations on the ground and on board ships.

Instrument Checks

"The rocket's flight was also used to check the performance of certain scientific instruments and to make required measurements.

"In order to gather further experimental data, tests of powerful multistage ballistic rockets will be continued.

"The successful launching ensures further advances of Soviet science towards the conquest of outer space and the study of planets of the solar system."

* * *

"It represents a big step forward in the planned exploration of space," Alexander Topchiev, vice-president of the U.S.S.R. Academy of Sciences, told a *Tass* correspondent after the news of the successful launching had been announced.

He described the rocket's accuracy as "fantastic."

Professor Evgeny Fyodorov, a well-known Soviet expert on rockets and sputniks and chief scientific secretary of the U.S.S.R. Academy of Sciences, said that the launching represented a new and major stage on the road towards the first flight to planets closest to the Earth.

"The amazing accuracy in hitting the target area, and also the passage of the nose cone through the dense layers of the atmosphere are extremely essential for the work being done on the recovery of rockets." commented a Ukrainian mathematician, Academician Boris Gnedenko.

Thermal Shield

"The results of the launching of a new and more powerful multi-stage ballistic rocket are amazing in three respects at least," stated Professor Boris Konstantinov, director of the Physical and Technical Institute of the U.S.S.R. Academy of Sciences.

"Firstly, the discrepancy between the target and the point where the nose cone simulating the last stage of the rocket hit the water represents only one six-thousandth part of the range of flight.

"Secondly, Earth-rocket-Earth radio contact was maintained throughout the trajectory, including the section in the dense layers of the atmosphere over the target area.

"Thirdly, the thermal shield of the nose cone fully protected it from destruction while it was moving at an immense velocity in the lower layers of the atmosphere.

Writing in the newspaper *Moskovskaya Pravda*, the prominent Soviet scientist Professor V. Dobronravov said that the rocket carried a model of the final stage which, after the conclusion of the current tests, will lift a package of instruments into outer space for further research.

He points out that the model of the final stage was specially protected so that it could penetrate the denser atmosphere.

* A second Soviet rocket launching occurred on 31 Jan., when the "penultimate stage, with a dummy last stage, reached the Pacific target area at 5.58 GMT." Following this, *Tass* announced that the present tests had been successfully completed and the target area was now free for shipping and aircraft.

"This is of paramount importance for further work on retrievable Earth satellites," he wrote.

Flights to Planets

"Although the rocket fired on 20 January is larger than the earlier Soviet space rockets," said Professor Dobronravov, "its last but one booster and the final stage developed a speed of more than 26,000 km.

"This shows that the final stage of the future larger space rocket will be able to develop, not only the first cosmic speed of 11·2 km./sec., but an even greater speed, sufficient for flights not only to the Moon but to the planets of the Solar System as well.

"This speed will be made possible by the engines installed in the new space vehicle."

"The development of a heavy earth satellite," Professor Dobronravov continued "may be useful for solving basic problems of space travel. The same holds true of the launching of heavier space rockets to planets of the Solar System. Thus, it will be possible to install a space orientation system for controlling the heavy Earth satellites. This system will enable more valuable scientific observations to be made.

"A heavy Earth satellite can even be fitted with a telescope which will photograph the starry sky, and we shall see what it is like without the Earth's atmosphere in the way.

Recovery Problems

"A heavy orientated Earth satellite can be provided with retro-rockets which will slow it down when it re-enters the denser atmosphere.

"And lastly, a heavy satellite can carry a device enabling it to make a safe descent through the whole atmosphere to the point of landing."

N. Varvarov, writing in the newspaper *Sovietsky Flot* ("Soviet Fleet"), devotes special attention to the problem of recovering space rockets, drawing attention to the difficulties involved.

He points out that a rocket experiences an immense air drag as it enters the atmosphere at a very great speed, which causes its intense heating and ultimate destruction.

In order to prevent the "super-heating," the period of the rocket's descent must be made as long as possible.

This means that the rocket should circle the Earth several times before reaching its surface. In addition, it must be borne in mind that its smooth ground-controlled descent within the prearranged area is impossible without continuous tracking. For this purpose there must be tracking stations not only on land but at sea as well.

"The initial experiment has shown that the use of shipping for this purpose is indispensable," says Varvarov.

He adds that the importance of the area of the world oceans will increase as further progress is made in the conquest of space.

The oceans and seas will be used not only as safe landing space for the parachute-assisted descent of individual stages of rockets, in order to preserve the costly structures for further experiments, but also as the area for automatic landings by spaceships.

(Left) Taken at a recent exhibition organized by the Canadian Astronautical Society in Toronto, this picture shows, left to right, Dr. P. A. Lapp, the Society's president, Mr. George Peace, U.S. Army Signal Corps, and Mr. A. E. Maine, CAS Secretary. Object of inspection is a full-scale model of Vanguard I and, at rear, a sectioned model of the Vanguard cloud-cover satellite.
(Right) Soviet visitor, Professor Alla G. Masevich, pictured with the editor (left) and former editor, Mr. Patrick Moore, at a reception given by The Society for Cultural Relations with the U.S.S.R. in London on 5 February.

The Aeroplane and Astronautics

Inflatable Satellite

Plans to launch a 100-ft. diameter inflatable sphere into orbit as a communications experiment were recently announced by the National Aeronautics and Space Administration.

Known as Project Echo, the experiment involves the launching of an aluminium-coated sphere into a 1000-mile-altitude orbit early this spring. Launching will be in a north-easterly direction from Cape Canaveral with an inclination of about 50° to the equator.

The object of the experiment is to test the feasibility of a passive reflector communications system on a global scale. The vapour-deposited aluminium skin of the big satellite will give it a high degree of radio wave reflectivity. After it is placed in orbit, N.A.S.A. hopes to establish two-way radio communications between the East and West Coasts of the United States by bouncing signals off the sphere.

The satellite will pass over all countries located between 50° north latitude and 50° south latitude. Its orbital period will be about 120 min. It is expected to pass over every portion of the United States except Alaska, enabling many independent researchers in the communications field to make use of the large sphere for propagation experiments. The maximum time of mutual visibility between the East and West Coasts for any one pass will be about 16 min.

The satellite, the first of three to be launched this year, will be an inflatable structure of 0·0005-in.-thick Mylar plastic coated with vapour-deposited aluminium to provide radio wave reflectivity of at least 98% up to frequencies of 4000 megacycles/sec. The sphere will weigh about 150 lb. From the ground, it will have the appearance of a zero magnitude star—about as bright as Vega.

Carried into orbit by a three-stage Delta rocket, the sphere will be folded inside a 28-in. diameter container; about 4-lb. of water in a plastic bag is carried inside the sphere. After separation from the final stage in orbit, the payload container opens by explosive bolts and the sphere begins inflation with the residual air inside the satellite. Inflation is completed as water in the plastic bag turns to vapour and expands.

The two major facilities involved in the experiment will be the N.A.S.A./Jet Propulsion Laboratory's Goldstone Tracking station in California and a Bell Telephone Laboratory station at Holmdel, New Jersey.

Goldstone will transmit a 2390 mc./s. signal for interception at Holmdel. The Bell antenna will transmit a 960 mc./s. signal to be picked up by Goldstone.

Project Echo is N.A.S.A.'s first step in a long range investigation of the application of artificial earth satellites to global communications. Such satellites may one day be used as relay stations for signal, voice and television transmission.

Weightlessness experienced in a jet-aircraft flying on a carefully-controlled parabolic path. Here a kitten floats out of the hand of Captain D. P. Parks strapped to his seat inside the cockpit of an F-94C at 25,000-ft.

The New York Times

N.P.L. Shock Tube

A hypersonic shock tube, now under construction at the National Physical Laboratory, Teddington, will be able to simulate some or all of the conditions applicable to the flight of missiles at extreme speeds in the upper atmosphere. The general principle of a shock tube is based on the sudden release of pressurized gas. Complex electronic equipment is required to collect data on the behaviour of the gas flow during its few thousandths of a second duration, when free-flight stagnation temperatures of the order of 15,000° F. may be achieved.

Many shock tubes have been constructed from surplus gun barrels, but for the purpose of studying the physics of air at very high temperatures, stainless steel is preferable. The new installation incorporates stainless steel bars specially bored with a 2-in. diameter hole to close tolerances, and capable of withstanding 1000 atmospheres pressure. The shock tube has been bored by the Sheffield firm of Keeton, Sons & Co. Ltd., members of the Firth Cleveland Group, who have developed special equipment for such assignments.

The required aerodynamic performance of the shock tube calls for extremely high "driver" pressure in the chamber, or breech, of the shock tunnel. Typical operating conditions require the containment of about 1 cu. ft. of hydrogen at a pressure 1000 times greater than

that of the atmosphere. This gas is then released, by rupturing a diaphragm, into the working section of the tube. A dump tank which has a total volume of about 200 cu. ft. and is exhausted to a pressure of 1 micron of mercury is fitted downstream of the working section to ensure the final equilization pressure in the apparatus does not exceed 5 atmospheres. The effect of the apparatus is to simulate flight at speeds up to about 18,000 m.p.h. at heights over 150,000 ft. (30 miles).

To meet the requirements of the National Physical Laboratory, Keetons had to produce fine finished bores from solid stainless steel bars, with flanges welded into the ends, in lengths varying from 1 ft. 6 in. to 7 ft. 6 in.

After rough boring straight from the solid to $1\frac{7}{8}$ in. diameter, a rough turning operation, off the bore, removed any eccentricity of the bore. Finish boring brought the holes to within 0·005 in. of finished size, and the bars were then finish turned on the outside diameters. The bores were finally honed to 2 in $-$ 000 $+$ 0·003 in., and the outside diameters ground to required limits.

Converting Human Wastes

Methods of sustaining the lives of spacemen on long flights by reconversion of human wastes into oxygen, food and water, are now under study by sanitary engineers at Illinois Institute of Technology's department of Civil Engineering.

Tightly sealed in a pressure capsule, or space-station, tomorrow's spacemen will literally be living in a small world of their own and must convert and re-use the materials they have at hand to sustain themselves. In this sense, they might be compared with fish living in an aquarium.

Here on earth, man lives in what is called an open ecological system—a balanced system consisting of plants and animals. The "little world" planned for the space man is called a "closed ecological system," a system with limited plant and animal resources. In such a closed system, converting the human wastes into forms that will serve as nutrients for plant growth is the key to the problem, according to Dr. Linvil Rich and Robert Matthern of I.I.T.

Such nutrients would provide food for algae, a basic, edible, plant form, which in turn, would

(1) provide a source of food; and

(2) act as an oxygen-carbon dioxide converter to provide the spacemen with oxygen for breathing.

Research shows that algae is nutritious for man, being abundant in protein and carbohydrates. The fact that it is a green plant means it contains chlorophyll and is capable of photosynthesis—the conversion of carbon dioxide into oxygen and plant food in the presence of light and water.

The Illinois Institute of Technology is seeking to find a "biological converter" that will efficiently convert organic solid wastes into inorganic materials. Experience thus gained will be used in designing the smallest and most rapid method of waste conversion in keeping with the space and weight limitations of space vehicles.

Subscriber's Lament

I joined the British Interplanetary Society to go to the Moon—
Reasonably soon.
I wanted to hear about landings on Venus and Mars
And thrilling Einsteinian flights to the stars.
But, whenever I opened the infernal
B.I.S. Journal,
Instead of pictures of exciting, space-suited people
Setting off in some great, gleaming ship as tall as a steeple,
All I find is a welter of maths
Describing their paths.

Confound all these Cleavers and Cleators—these dabblers
In propellants, parameters; pumps and parabolas—
Who flaunt their calculus, all spiky and bristly,
While the tone of their efflux grows more guided-missily!
I think it's indecent, filling the Society's publications
With all this rough-work and calculations.
How would they like it if physiologists detailed, in every issue
All the writhings and twitchings of lab-tortured tissue?
(Anyway, I thought it'd all been worked out years ago by Oberth and Esnault-Pelterie,
That terrible stuff, all Sigma—and Theta—and Delterie.)

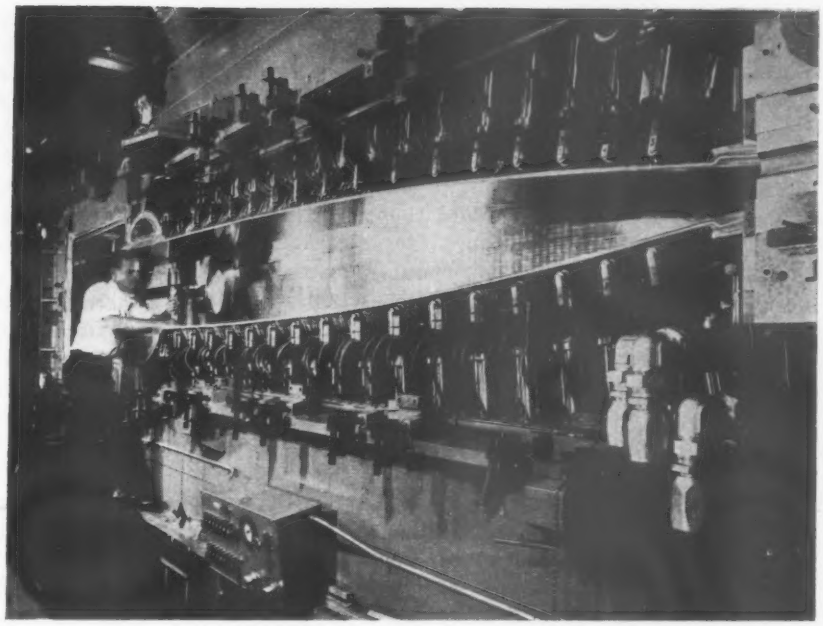
Let's hear more about spaceships and stations—
I'm sick of these endless specifications
Of Nikes and Matadors, Snarlers and Mice
(Which just hop about poor Earth's surface, like lice.)
They'll no more carry me to distant planets
Than a sixteenth-century gondola, drawn by gannets.
So come on, you theoreticians, let us reach for the sky
*(With a little help from the Ministry of Supply!)**
Build me a vehicle, find me a crew—
All I ask is a spaceship and a star to steer her to!

J. G.

** Fortunately for the poet, composed before the "take-over" by the Ministry of Aviation. Ed.*

Wind-Tunnel Testing at Mach 9.0

Details of the new hypersonic wind tunnel now in operation at the Jet Propulsion Laboratory in Pasadena, California



Jet Propulsion Laboratory

A new hypersonic wind-tunnel producing air speeds nine times that of sound was opened last September at the California Institute of Technology Jet Propulsion Laboratory in Pasadena. Financed by the U.S. Army Ordnance Corps, it is one of the first hypersonic tunnels in the United States capable of engaging in missile development testing on a high production basis.

Driving force of the new tunnel's closed-circuit system is compressed-air. There is a unique, flexible, two-dimensional nozzle and a 21-in. × 21-in. test section. The range of operation is between Mach 5.0 and 9.0.*

Construction of the new tunnel, the third to be built at J.P.L. since 1947, took about 3½ years and cost $3,500,000. Preliminary design specifications were developed by J.P.L. engineers, and detailed design, fabrication and erection were carried out by the Westinghouse Corp. Testing will be allocated equally among N.A.S.A. research programmes and Army and Air Force weapon development testing.

J.P.L.'s other two tunnels are continuous-flow supersonic tunnels. The 12-in. tunnel, built in 1947, is operated in a circuit which may be either closed or open. It has a testing range of Mach number 1.3 to 4. Its test section is 12-in. high and 12-in. wide. The nozzle is made of flexible steel plates which can be shaped for any Mach number by 12 pairs of manually operated screw jacks.

The 8-year-old 20 in. tunnel has an operating range of Mach number 1.3 to 5, and an 18- by 20-in. test section; it can function on a closed or open circuit. The nozzle for this tunnel consists of a symmetrical pair of flexible steel plates, each of which is supported by 22 pin-ended jacks. Jack servomechanisms are controlled by individual cams which move in unison on a shaft. By controlling the shaft position, the nozzle may be shaped to give the desired Mach number.

The new hypersonic tunnel will be used to study stability and control problems on many of the nation's most advanced missiles and aircraft by means of force balances and pressure distribution measurements. Also, heat transfer on practical shapes and the effects of such things as angle of attack, interfering flow fields and separated flow regions, both with and without various means of cooling, will be studied experimentally under carefully controlled conditions.

Flexible Nozzle

The outstanding feature of the new tunnel is its flexible, two-dimensional nozzle, the design of which was based on the experience gained with the supersonic tunnels. Both of these tunnels pioneered the use of flexible steel plates in establishing the contour of the nozzle to be used.

One major change was made, however, in the hypersonic nozzle design. In the earlier supersonic tunnels the top and bottom of the nozzle, including the throat, are made of stainless steel. In the hypersonic tunnel the throat—the tunnel's most critical part—is made of solid, beryllium-copper blocks. Beryllium-copper was chosen because it best combines high strength and high thermal conductivity.

It is the rectangle formed by the throat blocks that determines the tunnel's operating Mach number. When the tunnel is operating at Mach 9·0, for example, the width of the rectangle is 17 in., but the height is only 0·045 in.

These blocks were the most difficult part of the tunnel to produce. Their curved surfaces had to be machined

** Mach number is the ratio of the speed of motion of a body to the local speed of sound in its environments. Speed of sound at sea level is approximately 750 m.p.h. Thus, Mach 5.0 to 9.0 speeds are in the range of 3750 to 6750 m.p.h. at sea level.*

to tolerances of 0·0002 in., equipped with a cooling system able to carry 1475 gal. of water per minute at a velocity of 120 ft./sec. and be sufficiently rigid to withstand the maximum supply pressure of 1000 lb./sq. in. at 1350° F.

Following the throat blocks at the head of the nozzle are flexible steel plates located at the top and bottom of the working section. These plates are ½ in thick, 14 ft. long, 17 in. wide at the throat and 21 in. wide at the test section. They can be contoured by a system of 16 hydraulic jacks to refinements of as little as 0·0005 in., and can assume nozzle profiles to within 0·0002 in. of the theoretical shape required.

The nozzle sidewalls, also made of stainless steel, are 4 ft. high and 16 ft. long and are continuous from upstream of the throat to beyond the test section so as to eliminate any aerodynamic imperfections of a removable joint. This one-piece construction also facilitates the exposure of the functional parts of the nozzle. The sidewalls are diverged about ½° on either side for boundary layer growth and to achieve a more uniform flow inclination in the horizontal plane.

Although the design and operation of the new tunnel seem in many ways to be the same as in J.P.L.'s supersonic tunnels, there were problems to be solved associated with the high temperatures and pressures and the more critical tolerances encountered only in hypersonic flow.

The pattern of air flow, for example, in the new tunnel is very similar to, but not quite the same as, that in supersonic tunnels. In the supersonic tunnels the air is compressed and driven at subsonic speed through the supply section to the narrow throat of the tunnel's nozzle. From there the compressed air expands in the nozzle to low static pressure and temperature and races through the test section at the desired supersonic Mach number. After it leaves the test section, the air slows down and regains some of its pressure and most of its heat in the diffuser, from which point it travels at a subsonic rate back to the compressors, thus completing the circuit.

Air Pre-heated

But the main feature that distinguishes this tunnel from a conventional supersonic tunnel is that the air must be heated before it is introduced to the nozzle in order to prevent the formation of droplets of liquid air during the extreme expansion it encounters in that area.

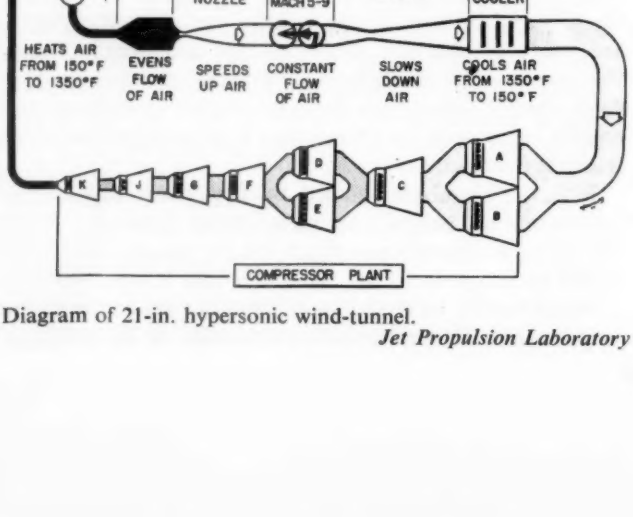


Diagram of 21-in. hypersonic wind-tunnel.
Jet Propulsion Laboratory

Therefore, a 4200 kilowatt electric heater was placed between the compressors and the supply section, so designed as to boost the temperature of the air coming in from the compressors from 150° F. to as high as 1350° F. The heating elements are 81 concentric pairs of 22-ft.-tall nichrome tubes through which the air makes a single pass. An electrical potential of 4000 volts is applied across the tubes which brings the tube wall temperatures up to as high as 1600° F. An automatic electrical control system operates a saturable reactor which controls the power input to maintain a constant air temperature. Air at 1350° F. supply temperature is sufficiently hot to prevent air liquefaction at a Mach number of nine.

In solving the air liquefaction problem however, J.P.L. engineers were faced with others.

After the air leaves the test section, it enters the diffuser—a device that reduces the velocity and increases the pressure of the air. In the case of a Mach 9.0 test the velocity is reduced to 30 m.p.h. and the pressure is increased from 1/20 lb./sq in. to four lb./sq. in. But a troublesome reaction occurs. The diffuser regains almost all of the heat the air had just prior to its entrance into the nozzle's throat. In the Mach 9.0 operation the temperature at the throat is 1350° F. and at the diffuser exit it is 1000°F.

Since the air temperature must be reduced to 150° F. before it re-enters the compressors, a tunnel aftercooler was installed between the diffuser and the compressors. The aftercooler selected was designed especially to cope with the high temperatures involved and to provide a reliability against water leaks. It has 1664 water tubes, 6800 sq. ft. of cooling area, and requires 2400 gal. min. of cooling water.

Another problem that had to be solved because of the high temperatures needed to avoid air liquefaction had to do with the cooling of the surfaces of the critical parts of the tunnel that came in contact with the hot air.

The important "hot spots" that have to be cooled in order for them to retain their dimensional stability are the supply section, nozzle, test section and the diffuser throat.

Water Cooling

The supply section is water-cooled on the exterior and thermally insulated on the interior, and a thin metal fairing is used to channel the hot air through the supply section, with insulation inserted between it and the water cooled walls.

The rest of the tunnel is cooled through a system of internal water jackets placed as close to the air-wetted surface as possible rather than on the outside.

Cooling the nozzle's throat blocks presented the most formidable problem since a tremendous amount of heat must be removed from a small area. The outer surface is 1200° F. and the cooling water flows in contact with

a surface that may be as warm as 160° F. It was essential, therefore, that the throat block's cooling system be treated to minimize the number of ions present that could form scale and increase the metal temperatures beyond desirable limits. For this system distilled or de-ionized water with anti-corrosive additives is used in a separate pressurized, closed-loop, recirculating system capable of pumping the coolant 120 ft./sec. (This system is pressurized to several hundred lb./sq. in. to prevent cavitation at this high water velocity.)

By restaging the seven centrifugal-type compressors that drove J.P.L.'s two supersonic tunnels and adding just two high-pressure compressors, sufficient mass flow and compression ratio became available to drive the new tunnel's 21 in. test section with a maximum supply pressure of 1000 lb./sq. in.

The record of the seven old compressors has been excellent. All of them have operated between 30 and 50 hr. per week on scheduled tests since being placed in operation. The 12-in. tunnel, requiring a continuous compressor plant of 4000 h.p., has been in service since 1947. The 20-in. tunnel, requiring 10,000 h.p. of continuous compressor plant has been heavily used since its initial operation in 1950.

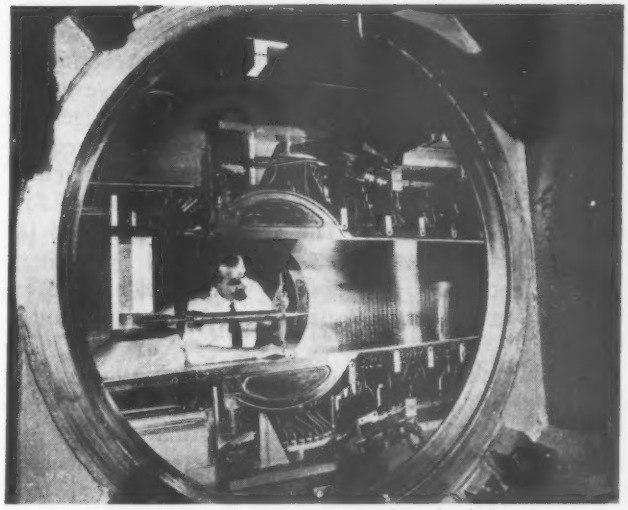
With the present compressor arrangement, the supersonic tunnels cannot operate while the hypersonic tunnel is running. But with the addition of two more compressors, all three tunnels will be able to operate simultaneously at their full potential. Until then the supersonic tunnels will run on a separate shift.

The electric motors driving the present compressor setup are rated in excess of 20,000 h.p., and with the addition of the two new units, the rating will be about 28,000 h.p.

By valving and multiple piping circuits, the compressors can be arranged in series or parallel or added or subtracted to provide the best compression ratio and volume requirements for different operations. The plant circuitry is such that the compressors can be changed from one tunnel to the other without being stopped. In order to reduce the air temperature build-up (about 300° F.) inside the compressors, each unit is equipped with a water tube aftercooler which cools the air to 150° F.

The cooling water system for the new compressors, tunnel, and tunnel aftercooler is divided into two parts. The tunnel, including the throat blocks, nozzle, test section and diffuser, is cooled with treated distilled water in order to prevent any chemical deposit buildup at the "hot spots." Any compressor plant heat exchangers which come in contact with 400° F. air, such as the tunnel aftercooler, are on the distilled water system. All other cooling jobs are supplied with water from a separate, treated raw water circuit. A cooling tower system, with a 4000-gal./min. distilled water section and a 7000 gal/min. raw water section, has been installed to meet these needs. The water pumps for this system total nearly 1000 h.p.

The air supply for the three J.P.L. tunnels is dried by first being refrigerated to zero ° F. in a 135-ton refrigeration plant and then passed through a 40 ft. high dryer



A model of the U.S. Army Sergeant SSM is adjusted in the working section of the new J.P.L. wind tunnel.
Jet Propulsion Laboratory

charged with 400,000 lb. of activated alumina, which is an aluminium refining by-product that can hold 2–3% of its own weight in water. The alumina, which has the appearance of small, porous stones, takes the remaining moisture out of the incoming air and provides the three tunnels with air of at least a −40° F. dewpoint.

Test Section

The test section was simply designed to give maximum access to the testing area. The top and bottom, except for a few structural areas, contain holes sealed with expendable plates. The sides are integral with the nozzle sideplate so that there is no flow disturbance at the junction of the nozzle and test section area. When the sideplates are removed, models 5 or 6 ft. long can easily be installed.

The model support for the new tunnel is crescent-shaped and can slide through the openings in the top and bottom of the test section so that a range of 30° of angle of attack can be provided. The support can also roll the model 360° about its longitudinal axis.

Mounted on the model support will be a water-cooled, internal strain-gauge balance system that can measure all of the aerodynamic forces and moments acting on the model being tested.

Hollowed models are placed on the tapered section at the forward end of the balance system. Cemented to the surface of the strain-gauge balance are resistance wires which stretch or shrink when the balance bends under the aerodynamic load. The minute movements caused by the bending produce a change in resistance which can be detected electrically on potentiometers outside the tunnel. (There is a potentiometer for each force and moment.)

Readings are made from each potentiometer and recorded in binary code on punched tape. The punched tape is then read by a binary code reader that changes the

code to numbers and feeds the tape to an electric typewriter that prints out the numbers representing the forces and moments acting on the model in the test section.

These numbers also can be processed to give aerodynamic coefficients for the benefit of the testing agency.

Pressures on the surface of the model are measured by manometers—banks of tubes, some containing mercury for high pressure measurements, and others silicon oil for measuring low pressure. The manometer is linked to small orifices in the surface of the model by tubing. Electrical pressure transducers with automatic data accumulation systems will also be used to record model pressures.

External and internal temperature measurements are obtained by thermocouples placed on the surface and inside the model. The temperature information obtained is relayed and read out on potentiometers or sensitive voltmeters.

An optical device, known as the Schlieren system, is used in the new tunnel to make visible the shock waves that appear in the flow about the model. Some changes from the conventional Schlieren method were necessary, however, because of the low air density encountered in hypersonic flow. The major modification made was the enclosure of the entire optical system in a 40 ft. pressure vessel which can be evacuated to a near vacuum.

Vanguard III

The tracking and telemetry transmitters within the Vanguard III satellite became silent last December. Launched on 18 September, 1959, Vanguard III transmitted tracking signals and scientific data over a period of 85 days. The satellite's silver-zinc batteries had a nominal lifetime of 90 days.

Last of the series, Vanguard III was instrumented to measure the Earth's magnetic field, X-rays from the sun, and environmental conditions in space. Shaped like an over-sized ice-cream cone—a 26-in. tapered tube extending from a 20-in. sphere—the satellite was fabricated of magnesium and fibre glass. The instrumented payload weights 50 lb., the attached third-stage casing contributing an additional 50 lb.

Scientists connected with the experiment report that the quantity and quality of data received was excellent. During its transmitting lifetime, Vanguard III travelled approximately 30,874,000 miles in its 938 orbits around the Earth. The Minitrack station at Santiago, Chile, was the last to interrogate the satellite at 9.01 a.m., E.S.T., 11 December. The last tracking report came from Woomera, Australia, which picked up signals the same day at 5.39 p.m., E.S.T.

The now silent satellite is expected to remain in orbit up to 40 years.

Processing "Solid" Propellents

A safer and faster method for the continuous processing of solid propellents is under development by the Rocketdyne division of North American Aviation, Inc.

Popularly known as "QuickMix," the new process is expected to provide a high degree of mobility for the manufacturing of solid propellents in the field and loading into large rocket motors. Further work in applying the process to several specific propellent formulations is being performed under contract with the manufacturing methods division, A.M.C., Aeronautical Systems Centre.

Principal objective of the new process is safety. In conventional methods of mixing solid propellents, the ingredients are brought together in batch mixers to produce quantities of finished propellent. As more sensitive propellents are used, and as larger quantities are processed, the hazards of fire and explosion during mixing are increased.

In the "QuickMix" process, propellent ingredients are thoroughly blended in a matter of seconds with only a very small amount of material being in the mixer at any given moment. Oxidizer is dried, sifted, and ground before being dispersed in a liquid carrier. Minor dry propellent ingredients are handled in a similar way. Liquid ingredients enter the system through a colloid mill for emulsifying with the liquid carrier. Where metallized propellents are required, the powdered metal also will be mixed with a liquid carrier, thus reducing the special hazards attendant to the handling of the fine metal powders.

The streams of oxidizer and other ingredients in their liquid carrier are blended at high speeds in a small mixer. Because of the fluidity, mixing is accomplished very rapidly with no appreciable heat build up and a very low power requirement. Propellent formation is immediate upon contact of the binder droplets and oxidizer particles.

"QuickMix" is also expected to offer advantages of low cost and versatility. A 5000-lb./hr. plant would be able to operate successfully at reduced rates. For field loading of large rocket motors containing thousands of pounds of propellent, the "QuickMix" plant and raw ingredients would be transported to the proposed firing site. The mixing of "QuickMix" propellent and loading of the rocket motor in the field thus would eliminate the Herculean task of transporting huge rocket boosters from the manufacturing plant.

The system promises to be applicable to most known solid propellents and can be quickly changed over from one formulation to another.

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The Outer Radiation Belt

Analysis of the data obtained with the help of Sputnik III and the Soviet space rockets warranted the conclusion that the intensity of the outer radiation belt, girdling the Earth at an altitude of up to 37,260 miles, could vary scores of times, Professor Sergei Vernov, declared in a recent report delivered at a general meeting of the Physics and Mathematics Department of the U.S.S.R. Academy of Sciences.

Soviet scientists, he said, linked this phenomenon with the magnetic storms which interfered with the circulation of charged particles in the radiation belt.

Describing the structure of the outer radiation belt, Professor Vernov said that it had now been proved that it consists of two main components—electrons of relatively low energy of up to 10,000 to 100,000 electron volts and high energy electrons of up to 1 to 3 million electron volts.

So far there was no theoretical explanation for the existence of such high energy electrons.

However, one thing was clear, namely, that they must generate gamma radiations so powerful that they would present a serious danger to future space travellers.

Professor Vernov drew attention to the possibility of the Earth's magnetic field at high altitudes being affected by intensive fluxes of low energy electrons.

According to data obtained from Sputnik III, the distance from the surface of the Earth to the outer radiation belt at one and the same latitude differed sharply at various points. In the U.S.S.R., for instance, it was 993 miles, and in the United States it was as low as 372 miles.

Professor Vernov believes that this is due to the displacement of the magnetic pole in relation to the centre of the Earth.

The artificial satellite technique, he said, made it possible to determine this displacement more accurately and it amounted to approximately 310 miles and not 186 miles, as was hitherto believed.

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Woomera for interrogating a satellite by radio for the purpose of relaying to the ground various measurements made during its last orbit.

The Baker-Nunn camera gives precise measurements of the satellite's position against time. It can photograph a tennis ball at a range of 1000 miles. In August, it was the first station in the world to photograph the American paddle-wheel satellite—from a distance of 14,000 miles. The central section of the satellite was only 2 ft. in diameter, and had four paddles, four ft. long, on each side.

The work at Woomera, as it can be seen, is not concerned solely with the weapons trials programme. There is also the quest for purely scientific information about the unknown quantities of the atmosphere and the void beyond. In their countless experiments, the scientists at Woomera have been adding to our knowledge of space, a necessary prelude to its mastery.

FUNDAMENTAL RESEARCH

After the recent record bathyscaphe descent, an American oceanographer is reported to have told Sir Julian Huxley: "I think the sea's bottom is just as important as the moon's behind".

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